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A spatial equilibrium analysis of the impact of transportation costs and policy changes on the export of U.S. beef and feed grains

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transportation costs and policy changes
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TABLE OF CONTENTS

CHAPTER I. INTRODUCTION

Japan has been the world's fastest-growing market for beef, mainly because of income growth (Coyle and Sanderson, 1991). In 1989, Korea was the fourth-largest export market for U.S. agricultural products. Although it has imposed restrictive policies on meat imports, Korea has been one of the largest and fastest-growing markets for U.S. corn and soybeans (Hayes and Meyers, 1990). Therefore, the United States, with cost advantages in producing beef and feed grains, has been concerned about the liberalization of markets for beef in both countries, where the livestock sector is related to their domestic political economies.

Since signing the Beef Market Access Agreement with the United States and the beef trade agreement with Australia in 1988, the Japanese government has liberalized its beef market by eliminating the restrictive quotas on beef imports and, instead, imposing tariffs. In 1990, the United States and the Korean governments agreed to increase the Korean beef import quota by 1993 and to renegotiate it in the same year. It is expected that the ongoing conferences about liberalization of international agricultural trade will accelerate removal of trade barriers on beef trade in the Pacific Rim.

Such a trend in international beef and feed-grains trade inevitably affects the welfare of each region in the United States as well as countries that participate in the beef and feed-grains trade. Even though the participants can benefit from free trade, the benefits will vary. Considering how each region or country is affected by price changes raises the following issues regarding transportation costs and trade policies. How will the beef market share in Japan and Korea be changed among the beef-exporting countries of the United States, Canada, and Australia? How will liberalization of the beef market in Japan and Korea affect feed-grain imports from the United States? How will producing and moving the high-quality beef and chilled beef as high value-added products be affected by transportation costs and trade policies?

Changes in transportation costs and trade policies due to liberalization lead to relative price changes of beef in each region, but the impact on price changes might depend on the structure of an economy. For example, the grain-rich regions that supply feed grains to others and also support their own region's production of high-quality beef will experience changes in production and consumption different from those of grain-poor regions and other countries that import the beef and feed grains. Each U.S. region does not have the same structure, as far as the beef and feed-grain industries are concerned. In 1989, Iowa, the Corn Belt, the Lake States, the Northern Plains, and the Mountain Region exported their surplus feed grains to domestic feeder markets and to other countries. Beef supply exceeded demand in Iowa, the Northern Plains, the Southern Plains, and the Mountain Region. Iowa, the Northern Plains, and the Mountain Region support the livestock on their territories with their own feed grains.

Iowa is at a disadvantage in serving coastal domestic meat markets because of distance and the lack of inbound loaded trucks that could haul beef out of Iowa. Nevertheless, Iowa enjoys a relative cost advantage in shipping grain to export ports rather than to feeder markets, and Iowa can utilize its own feed grains to produce high-quality beef. Because there are no transportation costs for feed, Iowa produces its high-quality beef at a lower cost than do regions which must import feed grains. With trade liberalization and the development of the cost-changing technology for transportation, Iowa should decide the comparative advantages of exporting feed grains and high-quality beef in order to maximize its position. The previously mentioned questions could be asked about Iowa specifically.

Insight into the changing trade pattern and welfare will give significant implications about transportation costs and policy changes. The spatial price equilibrium (SPE) model is appropriate for this purpose because it explains the interrelationship between factors such as commodities, agents, transport system, and government policies and regulations. In fact, the SPE model has been used for analyzing the interregional and international trade of energy resources and agricultural products.

This thesis uses the spatial price equilibrium model to investigate the impact of changes in supply, demand, transportation costs and liberalized trade policy, on the pattern of trade in high- and low-quality beef and feed grains. More importantly, the study will focus on the economic implications for U.S. regions, especially Iowa, as well as for the competing countries of Canada and Australia in exporting beef and feed grains to Japan and Korea.

Chapter II reviews the literature on the model and its empirical application to mainly the agricultural sector. The model for analysis and the assumptions underlying that model are discussed in Chapter III. The data required to implement the model for the interregional and international trade of beef and feed grains among 11 U.S. regions, 2 Canadian regions, Australia, Japan, and Korea are presented in Chapter IV. The descriptions of data are followed by the various scenarios and respective results in Chapter V. Scenarios include (1) trade policy changes of the Japanese and the Korean governments, (2) the increase in beef demand due to population growth or per capita beef consumption and income growth in Japan and Korea, (3) the increase of beef supply in Iowa, (4) the potential of chilled-beef exports, and (5) the domestic transportation cost changes in the United States. Chapter VI summarizes the major points of the thesis, followed by suggestions for further studies in Chapter VII.

CHAPTER II. LITERATURE REVIEW

Theoretical Development

The SPE model has been one of the classic models in economics and regional science since Samuelson (1952) formulated mathematical programming. Takayama and Judge (1971) developed the concept and algorithm. In particular, they showed that a competitive spatial price equilibrium can be found by maximizing Samuelson's net social payoff function, subject to constraints. Their model has two restrictive assumptions: the linear demand and supply function and a given transportation cost.

Recent theoretical developments of the SPE model have focused on the generalization of demand, supply, and transportation cost functions in a region. Expansion of the model necessarily involves the introduction of new formulations and solution algorithms, like other mathematical programming problems. The representative studies are as follows: fixed-point formulation (MacKinnons, 1976), the linear complementarity formulation (Asmuth, Eaves, and Peterson, 1979), the mathematical programming extension (Florian and Los, 1982; Rowse, 1981; Tobin and Friesz, 1983), and the nonlinear and generalized complementarity formulations (Friesz, Tobin, Smith and Harker, 1983; Fang and Peterson, 1980). More efficient solution algorithms for a generalized SPE model have been studied (Pang, 1981; Pang and Lee, 1981; Jones, Saigal, and Schneider, 1985). In addition to generalization of linear demand and supply functions, the profit-maximizing behavior of the transport firm is considered, instead of the given transportation cost functions (Harker, 1984).

Even though Takayama and Judge deal with the spatial monopoly problems, the SPE model assumes that all regional markets and the transportation market are perfectly competitive, and, thus, price in each market will equal marginal cost. Sheppard and Curry (1982) note that space confers an advantage on those producers who are closer to the consumers. The existence of these spatial advantages precludes the price-taking assumptions. Models incorporating imperfections in the spatial markets have been developed: a Cournot-Nash model (Greenhut and Greenhut, 1975; Rovinsky, Shoemaker, and Todd, 1980; Haurie and Marcotte, 1985), and a Bertrand-Nash model (McBride, 1983). However, these studies failed to provide detailed discussion of the possible alternative formulations and solution algorithms for their models. Harker (1986) presents alternative models of spatial competition and associated solution algorithms that overcome the problems associated with the perfect competition assumption with consideration of transportation network. While these researchers use the noncooperative Cournot-Nash equilibrium concept as the solution, Harker (1987) deals with cooperative game-theoretic concepts as a solution to spatial economic games involving spatially separated producers. Recently, the integration of the SPE model and the gravity model has been attempted to enhance the predictability on the interregional flow (Harker, 1988).

Empirical Studies

There have been numerous applications of the SPE model in such fields as coal, oil, natural gas, steel, agricultural products, and various raw materials. The empirical studies generally follow the theoretical development of the SPE model; they are concerned with nonlinear demand and supply functions and imperfect markets. The multicommodity model analyzing relationships among commodities is also one of the important issues. Applications of the SPE model to the agricultural sector are reviewed in the thesis.

Since assuming linear demand and supply curves give linear equilibrium conditions that can be solved by quadratic programming or linear complementarity algorithms, the SPE model always has solutions maximizing the given objective functions or satisfying equilibrium conditions. Because of its simplicity and ease of simulation, the SPE model with linear functions has been widely used. Hall, Heady, and Plessner (1968), Wilson and Koo (1985), and Koo (1982, 1984) analyzed the impacts of transportation costs and trade policies on grain exports by using the spatial equilibrium model based on linear or quadratic programming.

In some cases, using the linear demand and supply functions may lead to corner solutions, so applications of a model with nonlinear demand and supply functions have been proposed recently. Van der Sluis (1988), Van der Sluis and Hayes (1988), and Hayes, Hertzler, and Van der Sluis (1988) solve the nonlinear spatial equilibrium model for feed grains and beef that utilizes the nonlinear complementarity algorithm.

CHAPTER III. MODELS

Theoretical Model

The Takayama and Judge (1971) model presents multiproducts quadratic spatial equilibrium with the linear demand and supply functions. The criterion for the model is to maximize the net quasiwelfare function defined by Samuelson (1952). The quadratic objective function subject to linear constraints based on the linear demand and supply functions gives feasible solutions with certainty, but it may lead to unreasonable corner solutions due to elasticities of linear demand and supply functions.

As observed in Chapter II, Takayama and Judge's multiproducts model can be theoretically extended to the nonlinear objective function with nonlinear demand and supply functions. The transportation cost function can be also generalized. Because the nonlinear optimization approaches to the SPE model have difficulties in applying to empirical studies with respect to existing software, an alternative approach has been suggested (Van der Sluis, 1988; Van der Sluis and Hayes, 1988; Hayes, Hertzler, and Van der Sluis, 1988). It specifies the equilibrium conditions directly and solves them by using a nonlinear complementarity algorithm. In particular, assuming the constant elasticities of demand and supply functions, the model is transformed into the log-linear model, which can be easily manipulated for empirical studies.

Consider I regions and J commodities. Assume that demand and supply function in region i with constant price elasticities can be expressed as

$$D_{ij} = \alpha_{ij} \Pi_{k=1}^{J} P_{ik}^{\beta_{ijk}} \tag{1}$$

$$S_{ij} = \gamma_{ij}\, \Pi_{k=1}^{J}\, P_{ik}^{\delta_{ijk}}, \quad i = 1, 2, .., I \ \ (region), \quad j, k = 1, 2, .., J \ \ (commodity) \tag{2}$$

where D_{ij} is the demand for commodity *j* in region *i*; S_{ij} is the quantity supplied of commodity *j* in region *i*; P_{ij} is the price of commodity *k* in region *i*; α_{ij} is a demand shifter for commodity *j* in region *i*; β_{ijk} is the Marshallian elasticity in region *i* of the price of commodity *k* on the quantity of commodity *j*; γ_{ij} is a supply shifter for commodity *j* in region *i*; δ_{ijk} is the price elasticity in region *i* of the price of commodity *k* on the quantity of commodity *j*.

By taking logarithms and transforming them into price-dependent forms, both equations can be easily written as the inverse log-linear demand and supply functions. For region *i*, the demand function is

$$P_i = b_i \bullet a_i + b_i \bullet D_i \qquad i = 1, 2, \ldots, I \tag{3}$$

where

$$P_i = \begin{bmatrix} \ln P_{i1} \\ . \\ . \\ . \\ \ln P_{iJ} \end{bmatrix}, \quad b_i = \begin{bmatrix} \beta_{i11} & \cdots & \beta_{i1j} \\ . & \cdots & . \\ . & \cdots & . \\ \beta_{iJ1} & \cdots & \beta_{iJJ} \end{bmatrix}^{-1}, \quad a_i = \begin{bmatrix} \ln \alpha_{i1} \\ . \\ . \\ . \\ \ln \alpha_{iJ} \end{bmatrix}, \quad and \quad D_i = \begin{bmatrix} \ln D_{i1} \\ . \\ . \\ . \\ \ln D_{iJ} \end{bmatrix}.$$

Similarly, the supply functions for region *i* is

$$P_i = d_i \bullet c_i + d_i \bullet S_i \qquad i = 1, 2, \ldots, I \tag{4}$$

where

$$P_i = \begin{bmatrix} \ln P_{i1} \\ \cdot \\ \cdot \\ \cdot \\ \ln P_{iJ} \end{bmatrix}, \quad d_i = \begin{bmatrix} \delta_{i11} & \cdots & \delta_{i1J} \\ \cdot & \cdots & \cdot \\ \cdot & \cdots & \cdot \\ \delta_{iJ1} & \cdots & \delta_{iJJ} \end{bmatrix}^{-1}, \quad c_i = \begin{bmatrix} \ln \gamma_{i1} \\ \cdot \\ \cdot \\ \cdot \\ \ln \gamma_{iJ} \end{bmatrix}, \quad and \quad S_i = \begin{bmatrix} \ln S_{i1} \\ \cdot \\ \cdot \\ \cdot \\ \ln S_{iJ} \end{bmatrix}.$$

Since the assumption of perfect competition ensures that there is no restriction on the behaviors of arbitragers, the price in an exporting region i plus transportation costs and the tariff equivalent of any trade restrictions must be greater than or equal to the price in an importing region m. Otherwise, profit could be made by exporting commodity j from region i to region m, which violates the definition of equilibrium price. Therefore, the price-linkage condition can be expressed as

$$P_{ij} + t_{ijm} + T_{ijm} \geq P_{mj} \qquad i = 1, 2, \ldots, I, \;\; j = 1, 2, \ldots, J \tag{5}$$

where i is an exporting region; m is an importing region; j is commodities; t_{ijm} is the tariff equivalent in region m representing all trade restrictions on imports of commodity j from region i; T_{ijm} is the transportation cost from region i to region m for commodity j.

To be in the equilibrium state, market-clearing conditions are necessary, which requires that the total quantity demanded in each region equal the total quantity supplied.

$$D_i = S_i \qquad i = 1, 2, \ldots, I \tag{6}$$

where D_i and S_i are total quantity demanded and supplied in region i. Specifically,

$$D_i = \begin{bmatrix} D_{i1} \\ \cdot \\ \cdot \\ \cdot \\ D_{iJ} \end{bmatrix}, \qquad and \quad S_i = \begin{bmatrix} S_{i1} \\ \cdot \\ \cdot \\ \cdot \\ S_{iJ} \end{bmatrix}.$$

In addition to price-linkage and market-clearing conditions, the aggregate demand over all the regions in the model must equal the aggregate supply in all regions; that is, no inventory stock for next year's consumption is assumed in the model. In mathematical notation,

$$\sum_{i=1}^{I} D_i = \sum_{i=1}^{I} S_i, \qquad i = 1, 2, \ldots, I. \tag{7}$$

where D_i and S_i are the same as in equation (6).

Application to Beef and Feed-grain Trade

To apply the empirical model to beef and feed-grain trade, the following assumptions are necessary: (1) Each region is trading homogeneous commodities, that is, high-quality beef, low-quality beef, and feed grains. Quality discounts compensate for the quality of beef after freezing and during shipping. (2) Each region constitutes a single and distinct market for a commodity which is separated, but not isolated, by a transportation cost. (3) Feed grains are an intermediate input for the high-quality beef production but not for low-quality beef production. This assumption implies that substitutability or complementarity exists among three commodities, when each region consumes or produces them. (4) Nonlinear demand and supply functions with constant elasticities are assumed as the empirical model discussed in the previous section. (5) Perfect competition is assumed.

The 16 regions that are considered in the model are 11 U.S. regions, 2 Canadian regions, Australia, Japan, and Korea (Table 1). With regard to production of beef and feed grains and trade with the United States, Canada is divided into the east and west regions, whose centers are Toronto and Calgary, respectively. Countries excluded from the model are categorized as the rest of the world (ROW).

Table 1. Regions in the United States and Canada

Regions	States / Provinces
United States	
Iowa	IA
Corn Belt	IL IN MO OH
Northeast	CT DE MA ME MD NH NJ NY PA RI VT
Lake States	MI MN WI
Northern Plains	KS NB ND SD
Appalachia	KY NC TN VA WV
Southeast	AL FL GA SC
Delta States	AR LA MS
Southern Plains	OK TX
Mountain	AZ CO ID MT NM NV UT WY
Pacific	CA OR WA
Canada	
Western Canada	Manitoba, Saskatchewan, Alberta, British Columbia
Eastern Canada	Ontario, Quebec, New Brunswick, P.E.I., Newfoundland, Nova Scotia

Following the theoretical model and above assumptions, the model for high- and low-quality beef and feed grains in the 16 regions consists of 48 equations for market- clearing conditions, 45 price-linkage equations, and 3 quantity-linkage equations. Price- linkage equations (5) describe the present trade pattern. No trade barriers exit among U.S. regions, and the transportation cost is equivalent to the price differences. In international trade, tariff equivalents and quality discounts for frozen beef, as well as transportation cost for three commodities, are considered by the price-linkage equations. Since equation (6) shows that three markets in each region should be cleared, the equilibrium quantities of high- and low-quality beef and feed grains can be obtained by equating price-dependent supply and demand equations for each commodity. Equation (7) expresses that adding all unknowns (i.e., unknown equilibrium quantity for a commodity) and the quantity for ROW should be zero. The Generalized Inactive Nonlinear Optimization (GINO) software is used to solve the system of 96 equations for 96 unknowns.

One of the potential problems inherent in this approach is the feasibility of solutions. The number of equations and inequalities exceeds that of unknowns to be solved. The whole system of equations, equation (5) through equation (7), may cause overidentification for the unknowns. In this case, it may be difficult to identify not only feasible solutions, but also the effect of policy change on the equilibrium solutions. For the actual application, therefore, the following steps are suggested (Van der Sluis, 1988, p.34). First, replicate the current flow pattern of trade, rather than specify all potential price linkages as complementarity conditions. Next, simulate a specific policy by changing policy parameters given in the system of equations.

CHAPTER IV. DATA

Feed Grains

Table 2 lists feed-grain production, consumption, and price in 1989. Production is the feed and food purposes for specific grains, and the ratios of feed to food purposes in production for all regions are assumed to be identical. Consumption indicates the amount used for livestock or feed. Therefore, the differences between total production and consumption in Table 2 consist of the share of ROW, the amount for food, and feed-grain stocks.

Slightly different definitions of coarse grains are used for feed grains in each country because the characteristics of crop yields are different and, thus, it is difficult to get consistent data on feed grains. Especially, subdividing the United States and Canada into several regions leads to low availability of data by regions,

Table 2. Feed-grain production, consumption, and price (1989)

Regions	Production (mt)	Consumption (mt)	Price ($/mt)
Iowa	37,498,700	21,281,334	86.97
Corn Belt	62,492,771	15,870,711	96.45
Northeast	6,144,940	7,785,452	118.22
Lake States	34,067,954	14,687,853	87.50
Northern Plains	40,422,657	15,258,443	86.75
Appalachia	8,684,148	7,516,038	111.54
Southeast	2,860,307	8,892,626	114.37
Delta States	1,608,912	4,978,520	114.06
Southern Plains	8,779,782	12,099,446	100.90
Mountain	10,975,352	7,971,235	99.10
Pacific Region	2,562,621	7,135,734	127.76
Australia	6,949,000	4,953,000	125.98
Western Canada	15,155,900	11,918,580	96.45
Eastern Canada	14,523,200	4,121,808	103.98
Japan	381,000	22,210,000	135.05
Korea	643,000	7,668,000	135.05

Source: see Appendix 1.

for which consistency and accuracy of data are sacrificed. More detailed descriptions are as follows:

- For the United States, production is the sum of corn, barley, oats, and sorghum production, while consumption for these crops is estimated data (Wailes and Vermick, 1989). The prices in such major grain-producing regions as Iowa, the Corn Belt, the Lake States, the Northern Plains, and the Mountain Region are the weighted averages of the same grains. Prices in other U.S. regions are obtained by adding prices in major grain-producing regions to transportation cost between two regions, based on perfect competition and no domestic trade barriers.

- Production data for Canada is acquired by simply summing provincial production of corn, barley, oats, and rye (Ontario Ministry of Agriculture and Food, 1989). Consumption of feed grains per head of cattle in Western Canada is assumed to equal that of the Corn Belt in the United States and consumption of feed grains per head in Eastern Canada is assumed to equal that of the Northeast Region of the United States. The price of feed grains is obtained by adding the transportation cost between two Canadian regions to the U.S. average price of feed grains.

- Production and consumption data for Australia are for coarse grains from USDA (1990a) composed of corn, barley, oats, sorghum, rye, and mixed grain. The price is weighted average of barley, oats, sorghum and maize in crop year 1988-89 (Australia Bureau of Agricultural and Regional Economics, 1990).

- The sources of feed-grain production and consumption data for Japan and Korea are the same as those in Australia. Prices of feed grains in both countries are equal, because it is assumed that there are no transportation cost differences between Japan and Korea.

Beef Quantities

Tables 3 and 4 list the production, consumption, and price of high-quality (HQ) and low-quality (LQ) beef, respectively. All beef quantities produced and consumed are based on the carcass weight data for 1989. More assumptions and more complicated processes for obtaining the quantity of beef produced and consumed by regions as well as by qualities are needed. In this thesis, classification of beef by quality depends on the existing technology of cutting a carcass of cattle[1] and the share of each quality by Van der Sluis and Hayes (1988).

- In the United States, beef production data by qualities are obtained by total head and average weights of cattle by kinds and states (USDA, 1990d) and by the beef-cut technology. For beef consumption by regions and qualities, are used U.S. average weekly per capita beef expenditure of urban households in 1986 (Smallwood, 1990), retail price by cuts (National Cattlemen's Association), and U.S. per capita beef consumption in 1989 (Putnam, 1990).

- In Canada, production data is determined from the cutting technology, the number of cattle slaughtered, and the average warm carcass weight (Agriculture Canada, 1990b and 1990a). Consumption data of two types of beef are based on the assumption that taste preferences in Eastern Canada are equivalent to those in the Northeast Region of the United States and that taste preferences in Western Canada are the same as those in Midwest region of the United States.

- For the beef production and consumption data by qualities in Australia, the share of each quality in 1988 (Van der Sluis and Hayes, 1988) and the quantity

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[1] Usually the high-quality (HQ) beef means grain-fed or lot-fed beef, as the low-quality (LQ) beef does range-fed or grass-fed. Due to the data availability, cutting technology of carcass is used throughout the thesis, as the second best. I.e., 68% of a carcass of steer and heifer belongs to HQ beef, while remaining 32% of them and 100% of a carcass of cow and veal belong to LQ beef.

Table 3. High-quality beef production, consumption and price (1989)

Regions	Production (mt)	Consumption (mt)	Price ($/mt)
Iowa	371,421	61,977	1,619.83
Corn Belt	299,778	727,067	1,644.68
Northeast	119,681	1,139,194	1,710.90
Lake States	361,278	406,567	1,636.13
N. Plains	2,550,461	120,003	1,599.00
Appalachia	29,783	440,592	1,687.46
Southeast	45,834	507,917	1,699.77
Delta States	22,816	178,741	1,725.90
Southern Plains	1,077,954	384,020	1,655.79
Mountain	674,416	262,178	1,645.15
Pacific Region	291,692	710,911	1,725.10
Australia	149,200	8,900	1,599.00
W. Canada	335,698	118,395	1,473.00
E. Canada	169,639	347,734	1,615.78
Japan	541,420	838,502	6,722.00
Korea	9,005	14,331	6,652.00

Source: see Appendix 1.

Table 4. Low-quality beef production, consumption, and price (1989)

Regions	Production (mt)	Consumption (mt)	Price ($/mt)
Iowa	219,281	86,981	1,320.83
Corn Belt	338,208	1,020,402	1,345.68
Northeast	299,088	1,186,141	1,411.90
Lake States	446,236	566,387	1,337.13
Northern Plains	1,517,777	168,417	1,300.00
Appalachia	89,881	515,602	1,388.46
Southeast	167,894	594,389	1,400.77
Delta States	42,712	209,171	1,426.90
Southern Plains	781,138	449,398	1,356.79
Mountain	499,099	340,458	1,346.15
Pacific Region	309,492	923,170	1,410.78
Australia	1,342,400	673,100	862.00
W. Canada	201,728	166,208	1,198.00
E. Canada	146,717	350,527	1,340.78
Japan	6,534	171,498	5,381.00
Korea	90,501	143,312	5,401.00

Source: see Appendix 1.

of beef production and consumption in 1989 (Australia Meat and Livestock Corporation, 1989/1990) are utilized.

- Japanese beef production follows the cutting technology and government data on total production of beef by kinds (Japanese MAFF, Oct. 1990). Based on the share of each quality by Van der Sluis and Hayes (1988), beef consumption in 1989 is calculated.

- Because Korea has no grading system for beef, all quantities of beef produced and consumed are considered low-quality beef. However, 10% of low-quality beef is assumed to be the production and consumption for high-quality beef.

Beef Prices

All beef prices are based on the wholesale carcass weight data for 1989. The base prices and grading for the model used in this thesis are in Table 5.

Table 5. Comparison of base prices and beef grading

	Base price	HQ beef grading	LQ beef grading
U.S.A.	Omaha price	Grade 3 choice steers (318-363kg)	Cow carcass beef (average price)
Australia	New South Wales livestock market	Steer (320-350kg)	Cow (220-260kg)
Canada	Calgary and Quebec (average price)	A1,2 steer carcass and sides (225-325kg)	D1 Cow carcass and sides (225-325kg)
Japan	Tokyo Central meat wholesale market price	Wagyu steers (average price)	Dairy steer (average price)
Korea	Seoul wholesale market price	--	Korean native steer (average price)

Transportation Costs

Transportation costs as of January 1988 for feed grains (corn) among selected regions in the United States and between the United States and Japan/Korea were obtained from grain firms. On the basis of these costs, flows of feed grains among selected regions are setup for the empirical model. Table 6 shows that grain-rich regions in the United States, Australia, and Western Canada export feed grains to Japan and Korea, and also indicates that the Corn Belt, the Northern Plains, the Mountain Region, and Eastern Canada have an advantage with respect to transportation costs for exporting feed grains to grain-poor regions in the United States. Therefore, the domestic price differences are exactly equivalent to the transportation costs obtained. The ocean rate from Australia to Japan and Korea is based on Van der Sluis and Hayes (1988).

Table 6. Feed-grain price and selected transportation costs (1989)

Regions	Price ($/mt)	Transportation costs ($/mt) to						
		N.E.	Appa.	S.E.	Delta	S.P.	Pacific	Japan Korea
Iowa	86.97							48.08
Corn B.	96.45	21.77	15.09	17.92	17.61			38.60
N.E.	118.22							
Lake S.	87.50							47.55
N.P.	86.75					14.15		48.30
App.	111.54							
S.E.	114.37							
Delta	114.06							
S.P.	100.90							
Mt.	99.10						28.66	35.95
Pac.	127.76							
Aust.	125.98							9.07
W. Can.	96.45							38.60
E. Can.	103.98	14.24						
Japan	135.05							
Korea	135.05							

Source: see Appendix 1.

Beef transportation costs and origin-destination (O-D) pairs for the frozen beef primals in the selected U.S. regions, Australia, Japan, and Korea were obtained from livestock processing firms as of April 1989. Table 7 for high-quality and Table 8 for low-quality beef show those regions in which the production of beef exceeds consumption (such as Iowa, the Northern Plains, the Southern Plains, and Mountain Region) have the capability to export to Japan and Korea. Truck freight rates in the United States are used for the cost of moving frozen beef from each region to San Francisco (Pacific Region). Then, the ocean freight rate of $200.00/mt from San Francisco to Yokohama (Japan) and Pusan (Korea) is used. The price differences between O-D pairs of regions are the same as the transportation costs.

Because there are no available data on the freight rate in Canada, a truck rate is estimated by simple OLS regression method, on the basis of truck freight rate data for the United States.[2] It is also assumed that the ocean freight rate from Vancouver is $200.00/mt , the same rate as San Francisco to two ports in Japan and Korea.

Tariff Equivalents and Quality Discounts

[2] Using the 76 samples obtained to figure beef transportation cost in the United States, we used the OLS regression to estimated following relationship between transportation cost and mileages:

$$\underset{}{TRCOST} = \underset{(11.0)}{14} + \underset{(63.0)}{0.06}\ MILEAGE \qquad R^2 = 0.98$$

( ): t-values.

The assumption for the estimation is that transportation rate system is the same as that in the United States: i.e., transportation rate by truck is a linear function of the distance between two regions. The actual freight rate system in the United States is more than a linear relationship, but the explanatory power implied by the estimation is so reliable that estimated rates can be used for two regions whose rate is not available.

Table 7. High-quality beef price in each region, transportation costs, tariff equivalents, and quality discounts from selected regions to Japan and Korea (1989)

Regions	Price ($/mt)	Trans. costs ($/mt)	Japan Tariff eq. ($/mt)	Japan Quality discounts ($/mt)	Korea Tariff eq. ($/mt)	Korea Quality discounts ($/mt)
Iowa	1,619.83	328.26	2,757.31	2,016.60	2,708.31	1,995.60
Corn Belt	1,644.68					
Northeast	1,710.90					
Lake States	1,636.13					
N. Plains	1,599.00	310.78	2,795.62	2,016.60		
Appalachia	1,687.46					
Southeast	1,699.77					
Delta S.	1,725.90					
S. Plains	1,655.79	292.66	2,756.95	2,016.60		
Mountain	1,645.15	279.95	2,780.30	2,016.60		
Pacific	1,725.10					
Australia	1,599.00	142.80	2,963.60	2,016.60		
W. Canada	1,473.00	253.60	2,978.80	2,016.60		
E. Canada	1,615.78					
Japan	6,722.00					
Korea	6,652.00					

Source: see Appendix 1.

Table 8. Low-quality beef price in each region, transportation costs, tariff equivalents, and quality discounts from selected regions to Japan and Korea (1989)

Regions	Price ($/mt)	Trans. costs ($/mt)	Japan Tariff eq. ($/mt)	Japan Quality discounts ($/mt)	Korea Tariff eq. ($/mt)	Korea Quality discounts ($/mt)
Iowa	1,320.83	328.26	2,117.61	1,614.30	2,131.61	1,620.30
Corn Belt	1,345.68					
Northeast	1,411.60					
Lake States	1,337.13					
N. Plains	1,300.00	310.78	2,155.92	1,614.30		
Appalachia	1,388.46					
Southeast	1,400.77					
Delta S.	1,426.90					
S. Plains	1,356.79	292.66	2,117.25	1,614.30		
Mountain	1,346.15	279.95	2,140.60	1,614.30		
Pacific	1,410.78					
Australia	862.00	142.80	2,761.90	1,614.30		
W. Canada	1,198.00	253.60	2,315.10	1,614.30		
E. Canada	1,340.78					
Japan	5,381.00					
Korea	5,401.00					

Source: see Appendix 1

In Table 7 and Table 8, tariff equivalents and quality discounts for beef are presented to specify the trade barriers that cannot be explained by only transportation costs. The amount of quality discounts is assumed to be 30% of the domestic price. For feed grains, no tariff equivalents and quality discounts are assumed (see Table 6).

Elasticities

Table 9 shows the own- and cross-price elasticities of beef and feed grains.[3] Assuming indifferent taste among U.S. regions gives identical price elasticities of demand for beef. Price elasticities of demand for feed grains with respect to beef and feed grains are also assumed to be identical across the U.S. regions. All demand elasticities come from Van der Sluis and Hayes (1988), which are originally based on the various USDA publications and their own assumptions. Supply elasticities of high-quality beef and feed grains are derived from Schumway and Alexander (1988) and Van der Sluis and Hayes (1988), while those of low-quality beef in the United States are based on Van der Sluis and Hayes (1988). Demand elasticities of high-quality and low-quality beef in Canada are obtained from Charlebois (1987). Demand elasticities of feed grains and all supply elasticities in Western and Easter Canada are assumed to be identical with those in the Northeast and the Corn Belt region, respectively. It is also assumed that Japan and Korea have the same demand and supply elasticities.

[3] Demand for beef is not a function of feedgrain price, and supply of feedgrains depends only on own price. From the definition of low-quality beef, the quantity of its supply does not depend on the price of feedgrains.

Table 9. Price elasticities

Regions	Commodities	Demand			Supply		
		HQ beef	LQ beef	Feed grains	HQ beef	LQ beef	Feed grains
Iowa	HQ beef	-0.93	0.10	0	0.37	-0.05	-0.24
	LQ beef	0.25	-0.69	0	-0.16	0.37	0
	Feed grains	0.22	0.03	-0.47	0	0	0.60
Corn Belt	HQ beef	-0.93	0.10	0	0.37	-0.05	-0.24
	LQ beef	0.25	-0.69	0	-0.16	0.37	0
	Feed grains	0.22	0.03	-0.47	0	0	0.60
Northeast	HQ beef	-0.93	0.10	0	0.24	-0.03	-0.04
	LQ beef	0.25	-0.69	0	-0.11	0.24	0
	Feed grains	0.22	0.03	-0.47	0	0	1.47
Lake S.	HQ beef	-0.93	0.10	0	0.19	-0.03	-0.16
	LQ beef	0.25	-0.69	0	-0.08	0.19	0
	Feed grains	0.22	0.03	-0.47	0	0	0.71
N. Plains	HQ beef	-0.93	0.10	0	0.58	-0.08	0
	LQ beef	0.25	-0.69	0	-0.27	0.58	0
	Feed grains	0.22	0.03	-0.47	0	0	0.87
Appalachia	HQ beef	-0.93	0.10	0	0.40	-0.05	-0.20
	LQ beef	0.25	-0.69	0	-0.16	0.40	0
	Feed grains	0.22	0.03	-0.47	0	0	0.49
Southeast	HQ beef	-0.93	0.10	0	0.40	-0.05	-0.20
	LQ beef	0.25	-0.69	0	-0.16	0.40	0
	Feed grains	0.22	0.03	-0.47	0	0	1.25
Delta S.	HQ beef	-0.93	0.10	0	0.40	-0.05	-0.08
	LQ beef	0.25	-0.69	0	-0.16	0.40	0
	Feed grains	0.22	0.03	-0.47	0	0	1.25
S. Plains	HQ beef	-0.93	0.10	0	0.29	-0.03	0
	LQ beef	0.25	-0.69	0	-0.13	0.29	0
	Feed grains	0.22	0.03	-0.47	0	0	0.33
Mountain	HQ beef	-0.93	0.10	0	0.56	-0.08	0
	LQ beef	0.25	-0.69	0	-0.24	0.56	0
	Feed grains	0.22	0.03	-0.47	0	0	0.82
Pacific	HQ beef	-0.93	0.10	0	0.29	-0.03	0
	LQ beef	0.25	-0.69	0	-0.13	0.29	0
	Feed grains	0.22	0.03	-0.47	0	0	0.33
Australia	HQ beef	-0.50	-0.10	0	0.40	-0.05	-0.20
	LQ beef	0.25	-0.50	0	-0.16	0.40	0
	Feed grains	0.22	0.03	-0.36	0	0	0.83
W. Canada	HQ beef	-0.74	0.12	0	0.37	0.05	-0.24
	LQ beef	0.13	-0.41	0	-0.16	0.37	0
	Feed grains	0.22	0.03	-0.47	0	0	0.60
E. Canada	HQ beef	-0.74	0.12	0	0.24	-0.01	-0.01
	LQ beef	0.13	-0.41	0	-0.11	0.24	0
	Feed grains	0.22	0.03	-0.47	0	0	1.47
Japan	HQ beef	-1.81	0.21	0	0.50	-0.05	-0.06
	LQ beef	0.07	-1.02	0	-0.16	0.50	0
	Feed grains	0.22	0.03	-0.55	0	0	0.55
Korea	HQ beef	-1.81	0.21	0	0.50	-0.05	-0.06
	LQ beef	0.07	-1.02	0	-0.16	0.50	0
	Feed grains	0.22	0.03	-0.55	0	0	0.05

Source: see Appendix 2.

CHAPTER V. SCENARIOS

Five scenarios in Table 10 are established to analyze the impact that changes in transportation cost, trade policy and other factors in the model have on the trade of beef and feed grains. Scenarios suppose the current and future changes of economic environments around the Pacific Rim and instantaneous responses from the beef and feed-grain industries. Therefore, results from the scenarios provide implications under a specific situation and given data and assumptions, rather than solid predictions about what should be in the trade flows.

Since the model is built to provide as solutions the values for 1989 that are known to be true, the results from the various simulations are compared with the

Table 10. Scenarios

Scenario	Policy variables	Contents
I	Tariffs	Removal of tariff equivalents. Instead, impose A. 70% tariff on beef in Japan and Korea. B. 50% tariff on beef in Japan and Korea. C. 25% tariff on beef in Japan and Korea.
II	Income growth and taste change	Demand increase for beef in Japan and Korea by A. 20% B. 30% C. 40%
III	Production technology	Production increase of beef in Iowa by A. 50% B. 100%
IV	Transportation technology	Exports of chilled beef from beef exporting regions to Japan and Korea
V	Transportation costs	Change of transportation costs in the U.S.A. A. Iowa only adopts the rail rate for frozen beef. B. Iowa and some U.S. regions adopt.

1989 actual data as a base case (see Appendices 3, 4, and 5). In all cases, it is assumed that the price elasticities of demand and supply in each region remain constant; i.e., changing situation does not affect the shape of demand and supply curves. Only a demand increase in Japan and Korea (Scenario II) and a supply increase in Iowa (Scenario III) will change the shifters of demand and supply curves in corresponding regions, respectively.

Every region could gain the welfare by participating in trade under the general equilibrium model, but its magnitude depends on a region's demand and supply functions in the model which reflect consumer's preferences and production conditions in a region. Because the changes of welfare corresponding to the scenarios result in different degrees of the welfare accrued from the international and interregional trade, it is necessary to measure and to compare the changes of welfare among regions. By doing this, we can evaluate the results of each scenario. Theoretically, the welfare change can be measured by finding the sum of consumer's and producer's surplus. Empirically, however, the change of consumer'ssurplus of beef and feed grains in a region cannot be determined by simply integrating a left area of the demand curve from the prices of the base case to the new prices, when all prices of 3 commodities in the model move to new equilibrium prices simultaneously.[1]

[1] As long as the commodities have the significant income effect, consumer's surplus depends on the path of the price changes. This is a drawback of the concept of consumer's surplus, even though it is conceptually useful in comparing the results of policies in the welfare economics. Therefore, the welfare changes of each scenario are not considered in this thesis because of income effect in beef demand.

Scenario I: Decrease in Tariff on Beef Imports in Japan and Korea

In Scenario I, Japan and Korea remove beef import quotas and replace them with tariffs, as in the 1988 agreement between the United States and Japan. It is assumed that Australia and Canada as beef exporters and Korea as a beef importer follow the precedent agreement between the United States and Japan. The detailed tariffs used in scenario I are shown in Table 11, where the tariffs are applied to beef-surplus regions -- 4 U.S. regions, Australia, and Western Canada.[2] A series of these policy changes on the beef trade does not shift the demand and supply curves and can only reduce the trade barriers, causing price difference between the regions.

Table 11. Assumed tariffs on beef in Japan and Korea (Scenario I)

	HQ beef ($/mt)			LQ beef ($/mt)		
Regions	70%	50%	25%	70%	50%	25%
Iowa	1,363.66	974.05	487.02	1,154.36	824.55	412.27
N. Plains	1,336.85	954.89	477.45	1,127.55	805.39	402.70
S. Plains	1,363.92	974.23	487.11	1,154.62	824.73	412.36
Mountain	1,347.57	962.55	481.25	1,138.27	813.05	406.53
Australia	1,219.26	870.90	435.45	703.36	502.40	251.20
W. Canada	1,208.62	863.30	431.65	1,016.12	725.80	362.90

Note: 70% tariff on beef in Japan and Korea means 0.7 x (each region's price + transportation cost).

With reduced barriers, HQ beef prices in all U.S regions, Australia, and Canada increase, while Japan and Korea face decreasing HQ beef prices (see Table 12 and Appendix 3). The rates of increase in Canada and Australia are

[2] Changes in tariffs on beef from these regions to Japan and Korea affect equilibrium quantity and price in the remaining regions through price-linkage equations and overall quantity-linkage equations in the model.

Table 12. Price changes in Scenario I

(Unit: $, %)

Regions		Base case	70% tariff	50% tariff	25% tariff	% change from base case 70%	50%	25%
Iowa	HQ beef	1,620	1,631	1,678	1,747	0.7	3.6	7.9
	LQ beef	1,321	1,109	1,149	1,206	-16.0	-13.0	-8.7
	Feed grains	87	87	87	87	0.01	0.1	0.4
N. Plains	HQ beef	1,599	1,675	1,715	1,774	4.8	7.2	11.0
	LQ beef	1,300	1,153	1,186	1,233	-11.3	-8.8	-5.1
	Feed grains	87	87	87	87	0.01	0.1	0.4
Pacific R.	HQ beef	1,725	1,775	1,818	1,881	2.9	5.4	49.0
	LQ beef	1,411	2,294	2,206	2,101	62.6	56.4	0.2
	Feed grains	128	128	128	128	0.01	0.09	0.7
Australia	HQ beef	1,599	1,961	1,967	1,984	22.6	23.0	24.1
	LQ beef	862	1,745	1,657	1,553	102.5	92.2	80.1
	Feed grains	126	126	126	126	0.01	0.1	0.3
W. Canada	HQ beef	1,473	1,861	1,864	1,877	26.3	26.5	27.5
	LQ beef	1,198	1,322	1,323	1,330	10.3	10.4	11.0
	Feed grains	96	96		97	0.01	0.1	0.3
Japan	HQ beef	6,722	5,340	4,997	4,579	-20.6	-25.7	-31.9
	LQ beef	5,381	4,206	3,917	3,561	-21.8	-27.2	-33.9
	Feed grains	135	135	135	135	0.01	0.09	0.2
Korea	HQ beef	6,652	5,319	4,976	4,558	-20.1	-25.2	-31.5
	LQ beef	5,401	4,212	3,923	3,567	-22.0	-27.7	-34.0
	Feed grains	135	135	135	135	0.01	0.09	0.2

Source: Appendices 3, 4, and 5.

higher than those of the United States. As HQ beef prices in all U.S. regions increase, demand for HQ beef decrease and supply of HQ beef increase. Therefore, HQ beef-rich regions including Iowa, the Northern Plains, the Southern Plains, and the Mountain Region increase its exports, as shown in Table 13; other regions decrease imports. Australia also increases HQ beef exports as tariff rates decrease. Western Canada is the most responsive region among the HQ beef

Table 13. Changes in trade and trade value from the base case to a 25%-tariff-imposing scenario (Scenario I)

(Unit: mt, $1,000)

Regions		HQ beef	LQ beef	Feed grains	Total
Iowa	Trade	16,719	-17,208	-184,020	
	Value	68,677	-35,936	-11,091	21,650
N. Plains	Trade	181,835	-97,435	-178,711	
	Value	748,979	-210,387	-7,846	560,746
Pacific R.	Trade	32,292	240,558	-214,582	
	Value	-4,755	81,696	-28,882	48,059
Australia	Trade	9,094	442,307	-314,825	
	Value	72,116	1,148,951	-39,146	1,181,921
W. Canada	Trade	47,536	1,854	-645,204	
	Value	177,118	7,159	-61,436	122,841
Japan	Trade	-787,023	-83,761	2,075,394	
	Value	-2,967,393	1,984	274,233	-2,691,176
Korea	Trade	-13,100	-82,093	708,612	
	Value	-48,560	-195,133	93,763	-149,930

Source: Appendices 3, 4, and 5.

Note: Because the Pacific Region, Japan, and Korea import beef and feed grains, negative figures in trade mean the increase of imports and positive figures mean decreased imports. Negative figures of trade in beef- and feed grain-exporting regions mean the decrease of exports, and positive figures mean the increased exports.

exporting regions with respect to increase rate of price, export and trade value. With 30% decrease of HQ beef price at 25%-tariff-rate-imposing scenario, however, quantities of HQ beef imports in Japan and Korea are increased by about 3.5 times and trade value is increased by more than 2.3 times.

The changes in LQ beef prices are different from changes in HQ beef prices under this scenario (see Table 12 and Appendix 4). New equilibrium prices of LQ beef in most of U.S. regions except the Pacific Region are lower than prices under the base case. LQ beef price changes in the Pacific Region and Australia are sharply increased at a 70%-tariff-imposing scenario, and after that they are slightly decreased, but still higher than the base case. Two Canadian regions show monotonically increases in LQ beef prices. LQ beef prices in Japan and Korea have decreasing trend, as tariffs are reduced. The new equilibrium quantities demanded and supplied seem to follow the changes in LQ beef price. That is, Table 13 shows that all U.S. regions including the Pacific Region and Eastern Canada reduce exports or import of LQ beef, while Australia and Western Canada export more LQ beef than the base case. With decreased prices, Japan and Korea expand demand for LQ beef, even if its rates of increase are lower than those of HQ beef.

Beef prices in Australia and Western Canada increased at a faster rate than beef prices in feed grain-rich regions of the United States, because Australia and Canadian beef industries are much smaller than the U.S. beef industry. However, feed grain-rich regions in the United States have an advantage of increasing HQ beef exports due to the increased HQ beef prices and decreased LQ beef prices under Scenario I. Australia has an advantage of increasing LQ beef exports due to the relatively higher rate of increase in LQ beef price than that of HQ beef price, while Western Canada has an advantage of HQ beef exports. Therefore, as the liberalization of beef market in Japan and Korea accelerates, the United States and Western Canada are still the main suppliers of HQ beef to Japan and Korea and Australia is an exporter of LQ beef to Korea and the Pacific Region of the United States

More specificially, Table 13 shows the changes in trade of beef and feed grains for some regions at a 25%-tariff-imposing scenario. It also gives the same implications as the prices changes under this scenario. That is, Australia exports LQ beef to the Pacific Region, Japan, and Korea, while Western Canada and feed grain-rich regions of the United States export HQ beef to Japan and Korea. Note that in Japan and Korea the decreasing rates of feed grains are much smaller than the increasing rates of beef. It means that feed grain-rich regions can expand the HQ beef exports without sacrificing their feed-grain industries.

Scenario II: Increase in Demand for Beef in Japan and Korea

Scenario II is more dramatic than any other scenario, because it took 50 years for total calorie consumption from animal product to increase from 10 % to 25% in Japan (Coyle and Sanderson, 1991). The income and population growth and the taste preference changes in both countries make this scenario valid in the long run. To specify the impact of the increased demand in Japan and Korea on equilibrium prices and quantities of the model, the changes in the beef price due to other economic conditions are not considered.

Increased demand for beef exogenously given in both countries shifts demand curves upward, respectively, and the supply curves remain unchanged. Curves in other regions are the same as those in the base case. We assume that demand for beef in Japan and Korea increases by 20%, 30%, and 40%.

Under this scenario, Table 14 shows that the prices of HQ and LQ beef in other regions are slightly increasing. With the increase of beef prices, demand for HQ and LQ beef are reduced and supply continues to increase at a mild rate. The beef prices in Japan and Korea increase, but change rates of the beef price from the base case are smaller than change rates in other regions. At a 40%-demand-for-beef-increase scenario (a 40% scenario), however, demand for HQ beef and LQ

Table 14. Price changes in Scenario II

(Unit: $, %)

Regions		Base case	20% demand inc.	30% demand inc.	40% demand inc.	% change from base case 20%	30%	40%
Iowa	HQ beef	1,620	1,658	1,677	1,696	2.3	3.5	4.7
	LQ beef	1,321	1,343	1,354	1,365	1.7	2.5	3.4
	Feed grains	87	87	87	88	0.3	0.5	0.7
Corn Belt	HQ beef	1,645	1,683	1,702	1,721	2.3	3.5	4.6
	LQ beef	1,346	1,368	1,379	1,390	1.7	2.5	3.3
	Feed grains	96	97	97	97	0.3	0.5	0.6
N. Plains	HQ beef	1,599	1,637	1,656	1,675	2.4	3.6	4.8
	LQ beef	1,300	1,322	1,333	1,345	1.7	2.6	3.4
	Feed grains	87	87	87	87	0.4	0.5	0.7
Australia	HQ beef	1,599	1,637	1,656	1,675	2.4	3.6	4.8
	LQ beef	862	884	895	907	2.6	3.9	5.2
	Feed grains	126	126	126	127	0.2	0.4	0.5
W. Canada	HQ beef	1,473	1,511	1,530	1,549	2.6	3.9	5.2
	LQ beef	1,198	1,220	1,231	1,243	1.9	2.8	3.7
	Feed grains	96	97	97	97	0.3	0.5	0.6
Japan	HQ beef	6,722	6,760	6,779	6,798	0.6	0.9	1.1
	LQ beef	5,381	5,430	5,414	5,426	0.4	0.6	0.8
	Feed grains	135	135	136	136	0.2	0.3	0.4
Korea	HQ beef	6,652	6,690	6,709	6,728	0.6	0.9	1.1
	LQ beef	5,401	5,423	5,434	5,446	0.4	0.6	0.8
	Feed grains	135	135	136	136	0.2	0.3	0.4

Source: Appendices 3, 4, and 5.

beef in Japan and Korea increase by 37.4% and 38.9%, repectively, and supply of HQ beef and LQ beef increase by 0.5% and 0.2%, respectively. It means that the supply curves are very inelastic with respect to price changes in HQ beef and LQ beef. Therefore, the increases of beef demand in Japan and Korea completely result in increase in imports of the HQ beef and LQ beef, as shown in Table 15.

Increased beef imports in Japan and Korea lead to benefits in Canada,

Table 15. Changes in trade and trade value from the base case to a 40%-increase-of-demand-for-beef scenario (Scenario II).

(Unit: mt, $1,000)

Regions		HQ beef	LQ beef	Feed grains	Total
Iowa	Trade	7,511	2,081	-13,380	
	Value	36,299	8,750	8,551	53,599
Corn Belt	Trade	31,796	13,022	123,495	
	Value	22,183	-12,364	42,931	52,750
Northern Plains	Trade	67,367	12,666	120,132	
	Value	297,894	77,296	25,575	400,765
Australia	Trade	2,435	26,354	-22,546	
	Value	14,761	53,786	-1,658	66,889
Western Canada	Trade	9,018	2,508	-54,596	
	Value	30,514	4,703	-3,358	31,859
Japan	Trade	-311,020	-66,756	-5,580	
	Value	-2,136,983	-369,563	-13,827	-2,520,373
Korea	Trade	-5,312	-55,598	-863	
	Value	-36,146	-305,146	-4,324	-345,616

Source: Appendices 3, 4, and 5.

Note: Negative figures in an import region mean increased quantity of imports or the value of imports, while those in an export region mean decreased quantity of exports or the value of exports.

Australia, and the regions in the United States by increasing exports or decreasing imports as Scenario I, showing the three characteristics (see Table 15). (1) beef-poor regions (e.g., the Corn Belt, the Northeast Region, the Lake States, etc.) import less HQ beef compared to LQ beef by reducing the demand for HQ beef. (2) beef- and feed grain-rich regions (e.g., Iowa, the Northern Plains, the Mountain Region, and the Southern Plains) increase exports of LQ beef as well as of HQ beef. (3) Australia having an advantage of LQ beef exports cannot supply the whole increment of LQ beef demand in Japan and Korea. Japan and Korea import LQ beef from the United States as well as Australia, so the relative magnitudes of benefit in the United States is greater than Australia in Scenario II and the U.S. benefits in Scenario I.

Scenario III: Increase in Production of Beef in Iowa

In Scenario III, the production of beef in Iowa is increased by 50% and 100%. In this case, beef supply curve in Iowa shifts downward, while demand moves along the initial curve. Curves in other regions remain constant.

The increase of beef quantity supplied in Iowa causes the decrease of beef price in all the regions (see Appendices 3 and 4). Decreases in beef prices induce more consumption and less production of HQ and LQ beef and less consumption and production of feed grains in every region except Iowa. Under this scenario, change rates of beef prices from the base case in Japan and Korea are relatively lower than other regions and change rates in Japan and Korea under other scenarios. It means that the impact of this scenario on Japan and Korea are smaller than other regions or that in other scenarios. As shown in Table 16, a 100% increase in Iowa beef supply causes trade to increase for HQ and LQ beef by 116% and by 161%, respectively. Therefore, Iowa realizes all the benefit from all the regions by reducing beef exports in beef-rich regions such as the Northern Plains, Australia, and Western Canada, and by increasing beef imports in beef-poor regions such as the Northeast and the Pacific Region, Japan, and Korea. Note that Table 16 indicates the greater loss of trade and value of trade in the Northern Plains than Japan and Korea.

Table 16. Changes in trade and trade value from the base case to a 100%-increase-of-beef-production-in-Iowa scenario (Scenario III).

(Unit: mt, $1,000)

Regions		HQ beef	LQ beef	Feed grains	Total
Iowa	Trade	357,951	213,556	15,219	
	Value	526,239	261,192	-9,588	777,844
Northeast	Trade	-48,070	-23,261	20,025	
	Value	3,467	22,114	3,457	29,037
Northern Plains	Trade	-70,931	-23,999	-134,430	
	Value	-302,849	-111,211	-28,488	-442,548
Australia	Trade	-2,520	-43,590	26,257	
	Value	-15,092	-75,350	1,948	-88,493
Western Canada	Trade	-9,735	-4,369	62,123	
	Value	-31,004	-7,115	3,774	-34,344
Japan	Trade	-19,185	-1,863	4,219	
	Value	-103,570	44	15,242	-88,283
Korea	Trade	-331	-1,860	-262	
	Value	-1,746	-6,718	-4,758	-3,706

Source: Appendices 3, 4, and 5.

Note: Negative figures in an import region mean increased quantity of imports or the value of imports, while those in an export region mean decreased quantity of exports or the value of exports.

Scenario IV: Exports of Chilled Beef from Beef-Exporting Countries to Japan and Korea

In Scenario IV, it is assumed that the beef-surplus regions export chilled beef to beef-importing regions and that, then, frozen beef is excluded in the model. Chilled beef has 30% more value than frozen beef because there is no quality deterioration as happens in the process of thawing. However, chilled beef raises transportation costs by 25% because of expensive air freight or shorter shelf life for ocean freight. The United States shipped 22,807 tons of chilled beef out of its total export of 149,552 tons to Japan in 1989; Australia shipped 93,693 tons out of

176,562 tons of total beef exports in the same year (Gorman and Mori, 1990, p.48). The air-freight chilled-carcass trade has increased rapidly in both countries since 1986.

Since the removal of quality discounts for beef and the addition of extra transportation costs are considered in the scenario, there is no shift in demand and supply curves. There are three patterns of beef price changes in Scenario IV. (1) The prices of HQ and LQ beef are increasing in Canada, Australia, and the all U.S. regions except the Pacific Region. (2) HQ beef price in the Pacific Region increases, but LQ beef price decreases. (3) In Japan and Korea, the price of HQ and LQ beef decreases. Beef prices in Australia, Japan, and Korea are more sensitive than the United States and Canada, and Australia. In the U.S. and Canadian regions, the prices of HQ beef are more sensitive than LQ beef prices, but in Australia, vice versa.

Table 17 shows changes of trade in Scenario IV, which follows the price changes in each region. That is, the beef- and feed grain-rich regions (Iowa, the Northern Plains, the Southern Plains, and the Mountain Region) in the United States, Australia, and Western Canada get the benefit by exporting more HQ and LQ beef and by reducing feed-grain exports in order to produce more HQ beef; other U.S. regions (beef-poor and/or feed grain-poor regions) and Eastern Canada decrease beef imports by demanding less and supplying more beef; the Pacific Region decrease more HQ beef imports, but increase LQ beef imports; Japan and Korea import HQ beef by 3 times and 2 times, respectively.

In this scenario, Japan and Korea decrease feed-grain imports and, instead, increase HQ beef and LQ beef exports (see Table 17). Australia cannot supply enough beef, especially LQ beef, to Japan and Korea because of small beef industry. Therefore, beef-surplus regions in the United States can have ability to export LQ beef as well as HQ beef to Japan and Korea due to the decreased domestic consumptions which corresponds to higher beef prices in Scenario IV.

Scenario V: Changes in Transportation Costs in the United States

In Scenario V, two changes in domestic transportation costs in the United States are considered. The first one is that only Iowa adopts the railroad

Table 17. Changes in trade and trade value from the base case to a chilled-beef-trade scenario (Scenario IV).

(Unit: mt, $1,000)

Regions		HQ beef	LQ beef	Feed grains	Total
Iowa	Trade	14,812	1,796	-319,126	
	Value	69,657	10,768	-23,312	57,113
Northeast	Trade	80,385	14,349	-121,655	
	Value	1,175	-38,197	-14,874	-51,896
Northern Plains	Trade	129,867	10,800	-181,337	
	Value	579,399	105,144	-8,756	675,787
Pacific Region	Trade	62,315	-33,700	-122,187	
	Value	52,928	-34,727	-16,922	1,279
Australia	Trade	6,140	61,853	-123,435	
	Value	37,230	132,998	-15,028	155,200
Western Canada	Trade	19,437	3,824	-253,767	
	Value	66,389	7,779	-23,643	50,526
Japan	Trade	-607,254	-61,523	1,687,342	
	Value	-2,459,849	1,795	222,252	-2,235,803
Korea	Trade	-10,324	-60,255	582,428	
	Value	-40,930	-157,931	76,857	-122,004

Source: Appendices 3, 4, and 5.

Note: Negative figures in an import region mean increased quantity of imports or the value of imports, while those in an export region mean decreased quantity of exports or the value of exports.

transportation as the means for moving frozen beef from Iowa to the West coast, while other U.S. regions continue to use truck transport. The second one is that beef- and feed grains-rich regions, including Iowa, follow the Iowa's transportation technology. The main point of this scenario is to show how the competitive position of Iowa beef and feed-grain industries will be affected as other competitive regions respond to Iowa's choice.

According to transportation cost data obtained from the livestock processing firms for 1989, the truck freight rate for beef is \$128.26 from Des Moines (Iowa) to San Francisco, while the railroad rate is \$42.26. Using the railroad to ship frozen beef reduces domestic transportation costs from Iowa to the West coast by 67%, thereby decreasing the total transportation costs from Iowa to Japan and Korea by 25%. On the basis of these costs, Table 18 is constructed for the scenario.

When only Iowa changes from truck to railroad, the new equilibrium prices of HQ and LQ beef are increased by more than 5%. Those in other regions are very slightly decreased (Table 19 and Appendices 3 and 4). In Table 20, regions

Table 18. Transportation costs of beef to Japan and Korea (Scenario V)

(Unit:U.S.\$/mt)

	Base	Iowa[a)]	Selected regions[b)]
Iowa	328.26	242.26	242.26
Northern Plains	310.78	310.78	236.50
Southern Plains	292.66	292.66	230.53
Mountain Region	279.95	279.95	226.34
Australia	142.80	142.80	142.80
Western Canada	253.60	253.60	253.60

Note: a) Only Iowa adopts the rail freight rate for frozen high-quality and low-quality beef.

b) Iowa and other beef- and feedgrains-rich regions in the United States follow the same railroad rate.

competitive with Iowa, such as the Northern Plains, the Mountain Region, and Australia decrease HQ beef and LQ beef exports, while they export more feed grains. Despite positive gains from feed-grain exports, these regions realize the negative benefits in trade value because of insensitive feed-grain prices. Other

Table 19. Price changes in Scenario V

(Unit: $, %)

Regions		Base case	Iowa	Selected regions	% change from base scenario	
					Iowa	Selected regions
Iowa	HQ beef	1,620	1,704	1,646	5.2	1.6
	LQ beef	1,321	1,405	1,358	6.4	2.8
	Feed grains	87	87	87	0.1	0.0
Northeast	HQ beef	1,711	1,709	1,726	-0.1	0.9
	LQ beef	1,412	1,410	1,437	-0.1	1.8
	Feed grains	118	118	118	0.08	0.0
N. Plains	HQ beef	1,599	1,597	1,614	-0.1	0.9
	LQ beef	1,300	1,298	1,325	-0.1	2.0
	Feed grains	87	87	87	0.1	0.0
Pacific	HQ beef	1,725	1,723	1,719	-0.1	-0.3
	LQ beef	1,411	1,409	1,362	-0.1	-3.5
	Feed grains	128	128	128	0.07	0.0
Australia	HQ beef	1,599	1,597	1,540	-0.1	-3.7
	LQ beef	862	860	813	-0.2	-5.7
	Feed grains	126	126	126	0.07	0.0
W. Canada	HQ beef	1,473	1,471	1,414	-0.1	-4.0
	LQ beef	1,198	1,196	1,149	-0.1	-4.1
	Feed grains	96	97	96	0.09	0.0
Japan	HQ beef	6,722	6,720	6,663	-0.03	-0.9
	LQ beef	5,381	5,379	5,332	-0.03	-0.9
	Feed grains	135	135	135	0.07	0.0
Korea	HQ beef	6,652	6,650	6,593	-0.03	-0.9
	LQ beef	5,401	5,399	5,352	-0.03	-0.9
	Feed grains	135	135	135	0.07	0.0

Source: Appendices 3, 4, and 5.

Table 20. Changes in trade and trade value from the base case to transportation-costs-change scenarios (Scenario V).

(Unit: mt, $1,000)

		Iowa				Selected regions			
Regions		HQ beef	LQ beef	Feed grains	Total	HQ beef	LQ beef	Feed grains	Total
Iowa	Trade	8,248	5,852	-246,213		2,491	2,980	-95,787	
	Value	40,087	19,392	-20,041	39,438	12,319	8,952	-8,404	12,866
N.E.	Trade	-1,062	-638	11,347		7,283	12,943	-19,484	
	Value	91	504	1,202	1,796	-2,559	-3,892	-2,295	-8,746
N. Plains	Trade	-1,597	-686	46,355		10,537	15,123	-42,230	
	Value	-7,094	-3,026	6,187	-3,933	53,701	54,260	-3,780	103,551
Pacific R.	Trade	-719	-521	4,764		292	-24,974	12,702	
	Value	-456	236	216	-4	2,947	-3,988	1,645	605
Australia	Trade	-80	-1,158	6,697		-1,930	-36,460	49,426	
	Value	-390	-2,057	1,015	-1,432	-11,311	-62,390	6,216	-67,485
W. Can.	Trade	-300	-120	16,888		-7,439	-3,738	121,574	
	Value	-848	-200	1,909	861	-23,432	-6,033	11,710	-17,555
Japan	Trade	-458	-49	9,437		-14,108	-1,518	48,978	
	Value	-2,525	-1	-596	-3,122	-76,339	-24	6,722	-69,641
Korea	Trade	-8	-49	3,445		-243	-1,525	17,061	
	Value	-42	-181	-137	-361	-1,286	-5,558	2,336	-4,508

Source: Appendices 3, 4, and 5.

Note: Negative figures in an import region mean increased quantity of imports or the value of imports, while those in an export region mean decreased quantity of exports or the value of exports.

U.S.regions such as the Corn Belt, the Northeast, the Lake states, Appalachia, the Southeast, and the Delta States, get modest increase of benefits from increased beef imports with lowered beef prices and from decreased feed-grain imports. Under this scenario, Iowa reaps most of the benefits from Japan and Korea as well as the competitive regions mentioned above. Western Canada decrease beef exports, but increased feed-grain exports make it compensate losses from the beef industry. The noncompetitive regions get the small portion of benefits.

When domestic transportation costs in the selected regions listed in Table 18 are decreased, changes in beef prices are different. That is, the new equilibrium prices in the most of the U.S. regions except the Pacific Region increase mildly, while the beef prices in all other countries decrease. Because the competitiveness in terms of transportation costs in the beef-surplus regions of the United States is enhanced under this scenario, these regions can export more HQ beef and LQ beef and less feed grains. Therefore, this scenario redistributes the benefits to the these regions from the beef-poor regions in the United States and other countries. Iowa's gains are reduced due to the decrease of benefits from HQ and LQ beef and the increase from feed grains, as compared to the first case, but it still realizes more gains than it does in the base case. As shown in Table 20, the U.S. regions with new transportation costs, including Iowa, support decrease in supply of LQ beef from Australia, increase in demand for LQ beef from the Pacific Region, and increase in demand for HQ beef by Japan. They absorb more increased benefits from Australia, Western Canada, Japan, and Korea than in the base case and the first case of Scenario V.

CHAPTER VI. SUMMARY AND CONCLUSIONS

In this thesis, the impacts of changes in transportation costs, trade policies and economic conditions on the trade pattern of beef and feed grains in each region were analyzed. With the SPE model, five scenarios were examined, whose results give us some implications of changes of the policy affecting the beef and feed-grain trade pattern.

The SPE model provides the advantages for analysis of policy simulations, but limits numerically accurate projections due to its dependence on the data and assumptions. Because the SPE model depends on the given demand and supply functions and data and assumptions, it should be admitted that expansion of the data for subdivided regions in the United States and Canada, not aggregated data, sacrifices the accuracy and consistency.

Given assumptions on model and data, the results can be summarized as follows. (1) In Scenario I, the specialization in international beef market is established as the tariff rate decreases in Japan and Korea beef markets. That is, beef- and feed grains-rich regions in the United States, including Iowa, and Western Canada export more HQ beef to Japan and Korea, while Australia exports more LQ beef to the Pacific Region, Japan, and Korea. (2) In Scenario II, because the supply curves in Japan and Korea are inelastic with respect to price changes in beef, demand increase for beef in both countries induce to increase imports of HQ beef from the United States and of LQ beef from the United States and Australia, which means every region except Japan and Korea increases beef and feed grains supply and decreases demand for them to maximize the benefits. (3) In Scenario III, Iowa takes all benefits from the all other regions, because a decrease in beef price due to the production increase in Iowa causes more consumption and less production of beef and less production and consumption of feed grains in every region except Iowa, Iowa holds all benefits from all other regions. (4) In Scenario IV, the beef producers in beef- and feed grains-rich regions of the United States, Western Canada, and Australia are the major beneficiaries of chilled HQ beef trade due to the increased prices. However, Australia fails to increase chilled LQ beef enough to supply the increase of LQ beef in Japan and Korea. (5) When Iowa only adopts the railroad rate for the frozen beef in Scenario V, it produces more HQ and LQ beef supported by more production and consumption of its own feed grains than it does in the base case. It takes most of the benefits from the Japan, Korea and Pacific region as well as competitive regions such as the Northern plains, the Southern plains, the Mountain Region, and Australia. The competitive regions' adoption of new rate reduce Iowa's gains. The regions following Iowa's policy extract more benefits from Australia, Japan and Korea than in the base case and the case in which Iowa only adopts.

From the scenarios, the following implications can be drawn. (1) In the most of the scenarios, the situation of beef and feed-grain industries in each region is an important factor that determines a region's behavior and benefits. In Scenarios I, II, and IV, especially, a region of a similar type of industries behaves similarly. For example, Iowa, as one of beef- and feed grains-rich regions, shows the same responses as the Northern Plains and so on, under those scenarios. (2) As the liberalization of beef market and rapid increase of the beef demand in Japan and Korea (Scenario II) take place, the United States and Canada will be main exporters of HQ beef to Japan and Korea, while Australia will be an exporter of LQ beef to Japan, Korea and the Pacific Region. The specialization will be deepened as liberalization of trade accelerates. (3) Transportation costs affect sensitively each region's trade pattern among regions (Scenario V). Iowa can absorb most of benefits by changing the trade pattern if it develops new technology lowering the transportation costs. (4) Even if it is known that Australia precedes the United States and keeps know-hows in exporting chilled beef, Scenario IV implies a possibility that the beef-surplus regions of the United States have capabilities to export not only chilled HQ beef, but also even chilled LQ beef to Japan and Korea because of small beef industry in Australia.

In a tariffs-reduction scenario (Scenario I), Iowa increases the HQ beef exports and decrease the LQ beef and feed-grain exports. Iowa, an typical region of abundant beef and feed grains, specialize in exporting HQ beef whose price is increased, and reduces LQ beef and feed-grain exports by increasing its own consumption of LQ beef and by using feed grain for HQ beef production. In an increase of demand for beef scenario (Scenario II), Iowa increases exports of HQ beef and LQ beef at the same time, like the Northern Plains. Under this scenario, increased prices of beef make Iowa induce less consumption and more production of beef, leading to more beef exports. Because Australia cannot meet increased LQ beef due to the lower increase rates of beef prices than the beef-rich regions of the United States, Iowa can increase beef exports. In a producing-more-beef-in-Iowa scenario (Scenario III), Iowa takes the benefits of all other regions. In a chilled-beef-trade scenario (Scenario IV), Iowa shows similar pattern of behavior as Scenario II. Iowa maximizes benefits by exporting more beef and, instead, by reducing feed grains on the same reason as Scenario II. In an Iowa-adopting-new-transportation-technology scenario (Scenario V), Iowa takes most of benefits, giving small benefits to its noncompetitive regions, such as the Northeast Region. In a selected-regions-follow-Iowa scenario (Scenario V), Iowa behaves as in Scenario II and Scenario IV. That is, it enjoys the positive benefits like other beef-surplus regions. Compared to the case in which Iowa only adopts new transportation cost, its benefits are reduced, but are still higher than the base case.

Scenario III (an increasing-production-of-beef-in-Iowa scenario) is one which gives Iowa the biggest benefits because it takes all the benefits of the model from other regions, regardless of competitiveness. The second scenario which Iowa can choose in terms of benefits is to adopt more efficient transportation means than other regions (Scenario V). Unlike Scenario III, it is not realistic, because Iowa's monopoly of railroad rate for frozen beef is not possible. In the case of other scenarios, Iowa is not different from beef- and feed grains-rich regions. Increasing beef exports due to the increased beef prices brings more benefits to Iowa, rather than feed-grain exports because the prices of feed grains do not change very much in the model.

CHAPTER VII. SUGGESTIONS FOR FURTHER STUDIES

In this thesis, a nonlinear complementarity algorithm was used as an alternative of nonlinear optimization approach because of difficulties in applying to empirical studies with respect to existing software. With user-friendly software, however, the nonlinear optimization model could provide more detailed flows of trade among regions.

A comparative static equilibrium model use in this thesis is useful for analyzing the impacts of policy parameters under the given data and has been used for many researches, as reviewed in Chapter II. However, the dynamic processes of the adjustment for an impact are ignored, because it assumes simultaneous responses for the change of policies. While the static model enables us to evaluate various policies from a present point of view, a dynamic model can afford to provide more accurate projections and is appropriate for analysis of the agricultural products including the beef and feed grains whose production is different from the manufactured commodities with respect to production processes and exogenous factors.

Perfect competitive beef and feed-grain markets are assumed for the model so that transportation costs are the only barrier to free trade. If we imagine that a country has a bargaining power in exporting or importing beef and feed grains, the type of markets such as the oligopoly and the monopoly should be included in the model. In fact, this approach has been applied to the analysis for trade of energy and resources. The assumption of imperfect markets for beef and feed grains implies the existence of other trade barriers rather than transportation costs. Because both of industries are directly related to the domestic politics, for example, a game theoretic approach can be applied.

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APPENDIX 1. SOURCES OF DATA

A. Feed Grains

U.S.A.:
- Production: USDA (1990b).
- Consumption: Wailes and Vermick (1989).
- Price: USDA (1990c).

AUSTRALIA:
- Production: USDA (1990a)
- Consumption: USDA (1990a).
- Price: Australia Bureau of Agricultural and Regional Economics (1990).

CANADA:
- Production: Ontario Ministry of Agriculture and Food (1989).
- Consumption: Assumed
- Price: Assumed

JAPAN:
- Production: USDA (1990a).
- Consumption: USDA (1990a).
- Price: Japan Ministry of Agriculture, Fisheries and Forestry (1990).

KOREA:
- Production: USDA (1990a).
- Consumption: USDA (1990a).
- Price: Korea Ministry of Agriculture, Fisheries and Forestry (1990).

B. Beef

U.S.A.:
- Production: USDA (1990b).
- Consumption: Wailes and Vermick (1989).
- Price: USDA (1990c).

AUSTRALIA:
- Production: USDA (1990a)
- Consumption: USDA (1990a).
- Price: Australia Bureau of Agricultural and Regional Economics (1990).

CANADA:
- Production: Ontario Ministry of Agriculture and Food (1989).
- Consumption: Assumed
- Price: Assumed

JAPAN:
- Production: USDA (1990a).
- Consumption: USDA (1990a).
- Price: Japan Ministry of Agriculture, Fisheries and Forestry (1990).

KOREA:
- Production: USDA (1990a).
- Consumption: USDA (1990a).
- Price: Korea Ministry of Agriculture, Fisheries and Forestry (1990).

APPENDIX 2. The SOURCES Of PRICE ELASTICITIES

		Demand			Supply		
		HQ Beef	LQ Beef	Feed Grains	HQ Beef	LQ Beef	Feed Grains
USA	HQ Beef	8	8	-	5,8	5,8	5,8
	LQ Beef	8	8	-	5,8	5,8	-
	Feed Grains	7	7	9	-	-	5,8
AUSTRALIA	HQ Beef	7	2	-	7	2	7
	LQ Beef	7	7	-	2	7	-
	Feed Grains	2	2	9	-	-	9
CANADA	HQ Beef	3	3	-	1	1	1
	LQ Beef	3	3	-	1	1	-
	Feed Grains	1	1	1	-	-	1
JAPAN	HQ Beef	4	4	-	7	2	6
	LQ Beef	4	4	-	2	7	-
	Feed Grains	2	2	9	-	-	9
KOREA	HQ Beef	1	1	-	1	1	1
	LQ Beef	1	1	-	1	1	-
	Feed Grains	1	1	1	-	-	1

Note: A. The corresponding sources of elasticities in each country are as follows:

1. Assumed elasticities.
2. Assumed, based on the U.S. data by Van der Sluis and Hayes (1988).
3. Charlebois (1987).
4. Goddard (1988).
5. Schumway and Alexander (1988).
6. Tyers and Anderson (1988).
7. U.S. Department of Agriculture (1978).
8. U.S. Department of Agriculture (1987).
9. U.S. Department of Agriculture (1989).

B. Sources 2, 4, 6, 7, 8, and 9 are requoted from Van der Sluis and Hayes (1988).

C. Assumed that Japan and Korea have the same elasticities, and also assumed that demand elasticities for feed grains and supply elasticities for beef and feed grains in west Canada are identical to those of the Corn Belt; East Canada to the Northeast.

APPENDIX 3. HQ BEEF: RESULTS OF SCENARIOS

			Base case	Scenario I (Tariff on beef in Japan & Korea)			Scenario II (Demand increase in Japan & Korea)			Scenario III (Prod. inc. in Iowa)		Scenario IV (Chilled beef)	Scenario V (Trans. cost change in)	
				70%	50%	25%	20%	30%	40%	50%	100%		Iowa	Sel. regions
Iowa	Trade	(mt)	309,444	315,116	319,670	326,163	313,226	315,097	316,955	489,707	667,396	324,256	317,692	311,935
	Price	($/mt)	1,620	1,631	1,678	1,747	1,658	1,677	1,696	1,579	1,540	1,761	1,704	1,646
	Value	($000)	501,245	513,969	536,447	569,922	519,230	528,346	537,544	773,122	1,027,484	570,902	541,332	513,564
Corn Belt	Trade	(mt)	(427,290)	(382,418)	(367,796)	(346,521)	(411,170)	(403,276)	(395,494)	(445,072)	(462,769)	(366,983)	(428,146)	(421,868)
	Price	($/mt)	1,645	1,721	1,760	1,820	1,683	1,702	1,721	1,604	1,564	1,790	1,643	1,660
	Value	($000)	(702,754)	(658,148)	(647,486)	(630,699)	(691,807)	(686,224)	(680,571)	(713,715)	(723,953)	(656,853)	(703,361)	(700,097)
Northeast	Trade	(mt)	(1,019,514)	(960,600)	(941,042)	(912,624)	(997,745)	(987,095)	(976,600)	(1,043,594)	(1,067,583)	(939,129)	(1,020,576)	(1,012,230)
	Price	($/mt)	1,711	1,787	1,827	1,886	1,749	1,768	1,787	1,670	1,631	1,856	1,709	1,726
	Value	($000)	(1,744,284)	(1,716,819)	(1,718,970)	(1,721,490)	(1,744,811)	(1,745,030)	(1,745,218)	(1,742,608)	(1,740,817)	(1,743,109)	(1,744,193)	(1,746,843)
Lake S.	Trade	(mt)	(42,289)	(16,653)	(8,448)	3,479	(33,252)	(28,829)	(24,468)	(52,251)	(62,171)	(8,276)	(42,793)	(39,248)
	Price	($/mt)	1,636	1,712	1,752	1,812	1,674	1,693	1,712	1,595	1,556	1,781	1,634	1,651
	Value	($000)	(69,190)	(28,517)	(14,800)	6,303	(55,663)	(48,809)	(41,896)	(83,343)	(96,728)	(14,742)	(69,935)	(64,797)
N. Plains	Trade	(mt)	2,430,459	2,532,070	2,564,114	2,612,294	2,464,187	2,481,018	2,497,826	2,394,421	2,359,528	2,560,325	2,428,861	2,440,996
	Price	($/mt)	1,599	1,675	1,715	1,774	1,637	1,656	1,675	1,558	1,519	1,744	1,597	1,614
	Value	($000)	3,886,296	4,242,070	4,396,856	4,635,275	4,033,515	4,108,420	4,184,190	3,730,299	3,583,447	4,465,695	3,879,202	3,939,367
Appalachia	Trade	(mt)	(410,808)	(387,651)	(379,986)	(368,854)	(402,272)	(398,096)	(393,983)	(420,256)	(429,671)	(379,268)	(411,229)	(407,950)
	Price	($/mt)	1,687	1,764	1,803	1,863	1,725	1,744	1,764	1,646	1,607	1,833	1,686	1,702
	Value	($000)	(693,224)	(683,739)	(685,203)	(687,128)	(694,047)	(694,443)	(694,828)	(691,899)	(690,559)	(695,068)	(693,164)	(694,453)
Southeast	Trade	(mt)	(462,083)	(435,315)	(426,446)	(413,557)	(452,223)	(447,399)	(442,645)	(472,987)	(483,851)	(425,613)	(462,570)	(458,780)
	Price	($/mt)	1,700	1,776	1,816	1,875	1,738	1,757	1,776	1,659	1,619	1,845	1,698	1,715
	Value	($000)	(785,435)	(773,167)	(774,229)	(775,494)	(785,795)	(785,953)	(786,097)	(784,538)	(783,590)	(785,241)	(785,398)	(786,628)
Delta S.	Trade	(mt)	(155,925)	(151,827)	(147,875)	(142,342)	(152,449)	(150,747)	(149,069)	(159,765)	(163,586)	(142,718)	(156,095)	(155,827)
	Price	($/mt)	1,726	1,737	1,784	1,853	1,764	1,783	1,802	1,685	1,646	1,876	1,724	1,729
	Value	($000)	(269,111)	(263,648)	(263,760)	(263,758)	(268,883)	(268,759)	(268,628)	(269,175)	(269,201)	(267,686)	(269,113)	(269,361)
S. Plains	Trade	(mt)	693,934	710,178	726,197	748,924	707,872	714,743	721,549	678,668	663,619	747,516	693,259	694,335
	Price	($/mt)	1,656	1,666	1,714	1,783	1,694	1,713	1,732	1,615	1,576	1,806	1,654	1,658
	Value	($000)	1,149,008	1,183,432	1,244,373	1,335,233	1,198,882	1,224,163	1,249,668	1,095,848	1,045,536	1,349,650	1,146,593	1,151,537
Mountain	Trade	(mt)	412,237	442,003	454,971	473,953	425,057	431,407	437,717	398,367	384,786	463,087	411,625	409,751
	Price	($/mt)	1,645	1,695	1,738	1,801	1,683	1,702	1,721	1,604	1,565	1,798	1,643	1,639
	Value	($000)	678,193	749,393	790,712	853,784	715,374	734,296	753,437	639,006	602,139	832,656	676,415	671,712
Pacific	Trade	(mt)	(419,220)	(436,777)	(415,842)	(386,928)	(404,398)	(397,132)	(389,964)	(435,573)	(451,819)	(356,905)	(419,939)	(418,927)
	Price	($/mt)	1,725	1,775	1,818	1,881	1,763	1,782	1,801	1,684	1,645	1,878	1,723	1,719
	Value	($000)	(723,195)	(775,453)	(755,954)	(727,950)	(712,934)	(707,707)	(702,415)	(733,510)	(743,159)	(670,267)	(723,651)	(720,247)
Australia	Trade	(mt)	140,300	147,649	148,273	149,394	141,521	142,129	142,735	139,020	137,780	146,440	140,220	138,370
	Price	($/mt)	1,599	1,961	1,967	1,984	1,637	1,656	1,675	1,558	1,519	1,786	1,597	1,540
	Value	($000)	224,340	289,527	291,615	296,456	231,650	235,358	239,101	216,581	209,249	261,570	223,950	213,029
W. Canada	Trade	(mt)	217,303	263,431	263,627	264,839	221,851	224,096	226,321	212,396	207,569	236,740	217,003	209,864
	Price	($/mt)	1,473	1,861	1,864	1,877	1,511	1,530	1,549	1,432	1,393	1,632	1,471	1,414
	Value	($000)	320,088	490,180	491,279	497,206	335,186	342,854	350,602	304,134	289,084	386,477	319,240	296,656
E. Canada	Trade	(mt)	(178,094)	(121,575)	(121,242)	(119,642)	(172,019)	(169,037)	(166,092)	(184,703)	(191,255)	(153,442)	(178,389)	(187,614)
	Price	($/mt)	1,616	2,004	2,006	2,020	1,654	1,673	1,692	1,575	1,536	1,775	1,614	1,556
	Value	($000)	(287,762)	(243,581)	(243,251)	(241,697)	(284,458)	(282,754)	(281,016)	(290,853)	(293,672)	(272,403)	(287,906)	(291,992)
Japan	Trade	(mt)	(297,082)	(719,345)	(867,379)	(1,084,105)	(454,132)	(531,500)	(608,102)	(306,837)	(316,266)	(904,336)	(297,540)	(311,190)
	Price	($/mt)	6,722	5,340	4,997	4,579	6,760	6,779	6,798	6,681	6,642	4,928	6,720	6,663
	Value	($000)	(1,996,983)	(3,840,994)	(4,334,327)	(4,964,376)	(3,069,863)	(3,603,009)	(4,133,966)	(2,049,951)	(2,100,553)	(4,456,832)	(1,999,507)	(2,073,321)
Korea	Trade	(mt)	(5,326)	(12,239)	(14,748)	(18,426)	(8,009)	(9,330)	(10,638)	(5,494)	(5,657)	(15,650)	(5,334)	(5,569)
	Price	($/mt)	6,652	5,319	4,976	4,558	6,690	6,709	6,728	6,611	6,572	4,879	6,650	6,593
	Value	($000)	(35,428)	(65,094)	(73,387)	(83,988)	(53,577)	(62,594)	(71,575)	(36,321)	(37,174)	(76,359)	(35,471)	(36,715)

Note: Trade means supply minus demand; Value means trade value which is the multiply of price and trade volume.
Selected regions are Iowa, the Northern Plains, the Sourthen Plains, and the Mountain Regions.

APPENDIX 4. LQ BEEF: RESULTS OF SCENARIOS

			Base case	Scenario I (Tariff on beef in Japan & Korea)			Scenario II (Demand increase in Japan & Korea)			Scenario III (Prod. inc. in Iowa)		Scenario IV (Chilled beef)	Scenario V (Trans. cost change in)	
				70%	50%	25%	20%	30%	40%	50%	100%		Iowa	Sel. regions
Iowa	Trade	(mt)	132,300	107,023	110,534	115,092	133,342	133,862	134,381	239,562	345,856	34,096	138,152	135,280
	Price	($/mt)	1,321	1,109	1,149	1,206	1,343	1,354	1,365	1,290	1,260	1,383	1,405	1,358
	Value	($000)	174,746	118,690	127,056	138,810	179,086	181,282	183,495	309,039	435,938	185,513	194,138	183,697
Corn Belt	Trade	(mt)	(682,196)	(795,873)	(779,424)	(757,500)	(675,661)	(672,412)	(669,174)	(693,623)	(704,957)	(668,149)	(682,820)	(669,545)
	Price	($/mt)	1,346	1,199	1,232	1,279	1,368	1,379	1,390	1,315	1,285	1,413	1,344	1,371
	Value	($000)	(918,015)	(954,241)	(960,090)	(968,692)	(924,241)	(927,321)	(930,379)	(912,022)	(906,085)	(943,867)	(917,774)	(917,969)
Northeast	Trade	(mt)	(887,057)	(1,003,531)	(986,746)	(964,358)	(880,376)	(877,052)	(873,741)	(898,738)	(910,318)	(872,708)	(887,694)	(874,113)
	Price	($/mt)	1,412	1,265	1,298	1,345	1,434	1,445	1,457	1,381	1,352	1,479	1,410	1,437
	Value	($000)	(1,252,429)	(1,269,668)	(1,280,808)	(1,297,081)	(1,262,567)	(1,267,617)	(1,272,652)	(1,241,233)	(1,230,315)	(1,290,626)	(1,251,925)	(1,256,321)
Lake S.	Trade	(mt)	(120,150)	(185,804)	(176,288)	(163,608)	(116,373)	(114,494)	(112,623)	(126,753)	(133,303)	(112,021)	(120,511)	(112,847)
	Price	($/mt)	1,337	1,190	1,223	1,270	1,359	1,371	1,382	1,306	1,277	1,404	1,336	1,362
	Value	($000)	(160,657)	(221,189)	(215,645)	(207,824)	(158,193)	(156,921)	(155,622)	(165,581)	(170,197)	(157,290)	(160,948)	(153,753)
N. Plains	Trade	(mt)	1,349,359	1,213,169	1,229,693	1,251,924	1,355,687	1,358,855	1,362,025	1,337,248	1,325,360	1,360,158	1,348,673	1,364,482
	Price	($/mt)	1,300	1,153	1,186	1,233	1,322	1,333	1,345	1,269	1,240	1,367	1,298	1,325
	Value	($000)	1,754,171	1,399,161	1,458,566	1,543,784	1,792,537	1,811,932	1,831,468	1,697,228	1,642,961	1,859,315	1,751,146	1,808,431
Appalachia	Trade	(mt)	(425,720)	(477,741)	(470,174)	(460,078)	(422,684)	(421,174)	(419,670)	(430,999)	(436,233)	(419,125)	(426,008)	(419,911)
	Price	($/mt)	1,388	1,242	1,275	1,322	1,411	1,422	1,433	1,358	1,328	1,455	1,387	1,414
	Value	($000)	(591,097)	(593,246)	(599,276)	(608,035)	(596,278)	(598,862)	(601,440)	(585,149)	(579,359)	(610,016)	(590,823)	(593,679)
Southeast	Trade	(mt)	(426,494)	(489,116)	(480,076)	(468,002)	(422,852)	(421,040)	(419,233)	(432,839)	(439,123)	(418,620)	(426,841)	(419,484)
	Price	($/mt)	1,401	1,254	1,287	1,334	1,423	1,434	1,445	1,370	1,340	1,468	1,399	1,426
	Value	($000)	(597,421)	(613,391)	(617,806)	(624,266)	(601,719)	(603,853)	(605,975)	(592,974)	(588,602)	(614,432)	(597,231)	(598,239)
Delta S.	Trade	(mt)	(166,459)	(194,132)	(190,070)	(184,823)	(165,249)	(164,647)	(164,048)	(168,566)	(170,652)	(163,501)	(166,574)	(165,067)
	Price	($/mt)	1,427	1,214	1,255	1,312	1,449	1,460	1,472	1,396	1,367	1,498	1,425	1,440
	Value	($000)	(237,520)	(235,767)	(238,539)	(242,431)	(239,468)	(240,438)	(241,406)	(235,333)	(233,201)	(244,992)	(237,421)	(237,715)
S. Plains	Trade	(mt)	331,741	236,653	250,029	267,325	335,620	337,553	339,481	324,774	317,884	340,749	331,356	336,586
	Price	($/mt)	1,357	1,144	1,185	1,242	1,379	1,390	1,401	1,326	1,296	1,428	1,355	1,370
	Value	($000)	450,101	270,815	296,258	331,905	462,826	469,269	475,765	430,643	412,110	486,691	449,055	461,120
Mountain	Trade	(mt)	158,640	81,701	92,201	106,111	162,402	164,279	166,153	151,908	145,272	168,190	158,268	161,156
	Price	($/mt)	1,346	1,173	1,209	1,260	1,368	1,380	1,391	1,315	1,286	1,421	1,345	1,351
	Value	($000)	213,553	95,869	111,498	133,713	222,227	226,634	231,086	199,811	186,788	238,971	212,801	217,695
Pacific	Trade	(mt)	(613,677)	(309,758)	(337,177)	(373,119)	(608,211)	(605,493)	(602,783)	(623,228)	(632,693)	(647,378)	(614,199)	(638,651)
	Price	($/mt)	1,411	2,294	2,206	2,101	1,433	1,444	1,455	1,380	1,350	1,391	1,409	1,362
	Value	($000)	(865,764)	(710,664)	(743,767)	(784,068)	(871,573)	(874,453)	(877,316)	(860,038)	(854,396)	(900,491)	(865,528)	(869,752)
Australia	Trade	(mt)	669,301	1,225,159	1,175,430	1,111,608	682,590	689,150	695,655	647,506	625,711	731,154	668,144	632,841
	Price	($/mt)	862	1,745	1,657	1,553	884	895	907	831	802	971	860	813
	Value	($000)	576,940	2,138,492	1,947,792	1,725,891	603,568	617,081	630,725	538,203	501,590	709,938	574,883	514,550
W. Canada	Trade	(mt)	35,520	36,975	36,999	37,374	36,777	37,403	38,028	33,323	31,151	39,345	35,400	31,783
	Price	($/mt)	1,198	1,322	1,323	1,330	1,220	1,231	1,243	1,167	1,138	1,279	1,196	1,149
	Value	($000)	42,553	48,878	48,945	49,712	44,877	46,059	47,256	38,895	35,439	50,333	42,353	36,521
E. Canada	Trade	(mt)	(203,811)	(201,278)	(201,246)	(200,795)	(202,300)	(201,548)	(200,798)	(206,387)	(208,934)	(199,113)	(203,951)	(208,166)
	Price	($/mt)	1,341	1,465	1,466	1,473	1,363	1,374	1,385	1,310	1,280	1,422	1,339	1,292
	Value	($000)	(273,266)	(294,812)	(294,960)	(295,749)	(275,737)	(276,968)	(278,195)	(270,361)	(267,521)	(283,151)	(273,131)	(268,921)
Japan	Trade	(mt)	(164,964)	(210,977)	(226,406)	(248,725)	(198,473)	(215,129)	(231,720)	(165,910)	(166,827)	(226,487)	(165,013)	(166,482)
	Price	($/mt)	5,381	4,206	3,917	3,561	5,403	5,414	5,426	5,350	5,321	3,911	5,379	5,332
	Value	($000)	(887,671)	(887,354)	(886,739)	(885,687)	(1,072,395)	(1,164,800)	(1,257,234)	(887,649)	(887,627)	(885,877)	(887,673)	(887,695)
Korea	Trade	(mt)	(53,261)	(99,396)	(114,207)	(135,354)	(81,169)	(95,042)	(108,859)	(54,205)	(55,121)	(113,516)	(53,310)	(54,786)
	Price	($/mt)	5,401	4,212	3,923	3,567	5,423	5,434	5,446	5,370	5,341	3,925	5,399	5,352
	Value	($000)	(287,663)	(418,649)	(447,985)	(482,796)	(440,199)	(516,496)	(592,809)	(291,092)	(294,381)	(445,594)	(287,844)	(293,221)

Note: see Appendix 3.

APPENDIX 5. FEED GRAINS: RESULTS OF SCENARIOS

			Base case	Scenario I (Tariff on beef in Japan & Korea)			Scenario II (Demand increase in Japan & Korea)			Scenario III (Prod. inc. in Iowa)		Scenario IV (Chilled beef)	Scenario V (Trans. cost change in)	
				70%	50%	25%	20%	30%	40%	50%	100%		Iowa	Sel. regions
Iowa	Trade	(mt)	16,217,354	16,299,999	16,183,633	16,033,334	16,210,595	16,207,261	16,203,975	16,225,039	16,232,574	15,898,229	15,971,142	16,121,568
	Price	($/mt)	87	87	87	87	87	87	88	87	86	87	87	87
	Value	($000)	1,410,424	1,417,766	1,409,366	1,399,333	1,414,711	1,416,844	1,418,975	1,405,567	1,400,837	1,387,112	1,390,383	1,402,020
Corn Belt	Trade	(mt)	51,622,019	51,522,937	51,482,999	51,441,773	51,684,046	51,714,856	51,745,513	51,551,674	51,483,114	51,439,485	51,669,239	51,579,397
	Price	($/mt)	96	96	97	97	97	97	97	96	96	97	97	96
	Value	($000)	4,978,960	4,969,889	4,971,506	4,977,337	5,000,483	5,011,202	5,021,890	4,954,609	4,930,955	4,975,723	4,987,954	4,974,605
Northeast	Trade	(mt)	(1,640,518)	(1,688,820)	(1,721,117)	(1,764,851)	(1,649,444)	(1,653,876)	(1,658,267)	(1,630,388)	(1,620,493)	(1,762,173)	(1,629,171)	(1,660,002)
	Price	($/mt)	118	118	118	119	119	119	119	118	118	119	118	118
	Value	($000)	(193,942)	(199,668)	(203,669)	(209,181)	(195,493)	(196,266)	(197,034)	(192,189)	(190,485)	(208,816)	(192,740)	(196,237)
Lake S.	Trade	(mt)	19,380,101	19,286,967	19,238,471	19,179,687	19,405,542	19,418,221	19,430,853	19,351,274	19,323,178	19,180,426	19,414,803	19,340,936
	Price	($/mt)	88	88	88	88	88	88	88	87	87	88	88	88
	Value	($000)	1,695,756	1,687,788	1,685,587	1,684,099	1,703,816	1,707,835	1,711,843	1,686,643	1,677,785	1,683,641	1,700,459	1,692,239
N. Plains	Trade	(mt)	25,164,238	25,066,738	25,026,880	24,985,527	25,224,437	25,254,431	25,284,370	25,096,089	25,029,808	24,982,901	25,210,593	25,122,008
	Price	($/mt)	87	87	87	87	87	87	87	86	86	87	87	87
	Value	($000)	2,183,003	2,174,783	2,173,980	2,175,157	2,195,812	2,202,198	2,208,578	2,168,543	2,154,515	2,174,248	2,189,190	2,179,223
Appalachia	Trade	(mt)	1,168,099	1,120,622	1,085,252	1,035,716	1,148,742	1,139,104	1,129,511	1,190,020	1,211,364	1,039,192	1,176,182	1,149,186
	Price	($/mt)	112	112	112	112	112	112	112	111	111	112	112	112
	Value	($000)	130,290	125,005	121,175	115,842	128,476	127,569	126,663	132,330	134,302	116,202	131,293	128,175
Southeast	Trade	(mt)	(6,032,315)	(6,088,295)	(6,131,349)	(6,192,240)	(6,059,315)	(6,072,743)	(6,086,114)	(6,001,724)	(5,971,925)	(6,187,708)	(6,024,051)	(6,054,456)
	Price	($/mt)	114	114	114	115	115	115	115	114	114	115	114	114
	Value	($000)	(689,918)	(696,377)	(701,953)	(710,105)	(694,826)	(697,274)	(699,718)	(684,374)	(678,995)	(709,417)	(689,488)	(692,421)
Delta S.	Trade	(mt)	(3,369,603)	(3,351,906)	(3,382,094)	(3,423,510)	(3,384,255)	(3,391,542)	(3,398,806)	(3,353,007)	(3,336,853)	(3,458,246)	(3,364,974)	(3,372,864)
	Price	($/mt)	114	114	114	114	114	115	115	114	113	114	114	114
	Value	($000)	(384,338)	(382,351)	(386,155)	(391,537)	(387,027)	(388,368)	(389,707)	(381,303)	(378,360)	(395,415)	(384,100)	(384,694)
S. Plains	Trade	(mt)	(3,319,650)	(3,274,123)	(3,351,968)	(3,459,151)	(3,360,284)	(3,380,496)	(3,400,613)	(3,273,588)	(3,228,696)	(3,547,266)	(3,308,931)	(3,327,900)
	Price	($/mt)	101	101	101	101	101	101	102	101	100	101	101	101
	Value	($000)	(334,954)	(330,390)	(338,602)	(350,089)	(340,063)	(342,614)	(345,161)	(329,190)	(323,606)	(358,910)	(334,156)	(335,770)
Mountain	Trade	(mt)	3,004,137	2,985,341	2,948,150	2,899,092	2,998,898	2,996,308	2,993,721	3,010,088	3,015,916	2,869,685	3,017,455	3,008,929
	Price	($/mt)	99	99	99	99	99	100	100	99	98	99	99	99
	Value	($000)	297,711	295,877	292,504	288,190	298,094	298,285	298,473	297,276	296,851	285,189	299,291	298,172
Pacific	Trade	(mt)	(4,573,101)	(4,723,578)	(4,749,393)	(4,787,683)	(4,600,715)	(4,614,460)	(4,628,159)	(4,541,828)	(4,511,391)	(4,695,289)	(4,568,338)	(4,560,399)
	Price	($/mt)	128	128	128	128	128	128	128	127	127	128	128	128
	Value	($000)	(584,261)	(603,530)	(607,334)	(613,143)	(589,172)	(591,623)	(594,069)	(578,718)	(573,343)	(601,183)	(584,045)	(582,616)
Australia	Trade	(mt)	1,995,984	1,658,350	1,669,615	1,681,159	1,984,654	1,979,024	1,973,438	2,009,243	2,022,241	1,872,549	2,002,681	2,045,410
	Price	($/mt)	126	126	126	126	126	126	127	126	125	126	126	126
	Value	($000)	251,454	208,935	210,531	212,308	250,623	250,208	249,797	252,440	253,403	236,426	252,470	257,671
W. Canada	Trade	(mt)	3,237,299	2,572,905	2,585,015	2,592,095	3,209,820	3,196,209	3,182,703	3,268,656	3,299,422	2,983,532	3,254,187	3,358,873
	Price	($/mt)	96	96	97	97	97	97	97	96	96	97	97	96
	Value	($000)	312,238	248,181	249,624	250,802	310,553	309,714	308,880	314,149	316,012	288,595	314,146	323,948
E. Canada	Trade	(mt)	10,401,370	10,192,276	10,214,761	10,250,503	10,445,657	10,467,735	10,489,777	10,351,302	10,302,705	10,370,366	10,421,791	10,438,711
	Price	($/mt)	104	104	104	104	104	104	105	104	103	104	104	104
	Value	($000)	1,081,540	1,059,893	1,063,317	1,068,992	1,089,284	1,093,153	1,097,018	1,072,807	1,064,353	1,081,211	1,084,558	1,085,371
Japan	Trade	(mt)	(21,828,996)	(20,575,728)	(20,219,076)	(19,753,602)	(21,831,550)	(21,832,962)	(21,834,575)	(21,826,615)	(21,824,777)	(20,141,654)	(21,819,558)	(21,780,018)
	Price	($/mt)	135	135	135	135	135	136	136	135	134	135	135	135
	Value	($000)	(2,948,007)	(2,778,943)	(2,732,924)	(2,673,774)	(2,954,916)	(2,958,378)	(2,961,834)	(2,940,245)	(2,932,765)	(2,725,756)	(2,948,603)	(2,941,285)
Korea	Trade	(mt)	(7,024,998)	(6,602,185)	(6,478,262)	(6,316,386)	(7,025,361)	(7,025,591)	(7,025,861)	(7,024,778)	(7,024,736)	(6,442,570)	(7,021,553)	(7,007,937)
	Price	($/mt)	135	135	135	135	135	136	136	135	134	135	135	135
	Value	($000)	(948,727)	(891,688)	(875,639)	(854,964)	(950,885)	(951,968)	(953,051)	(946,303)	(943,969)	(871,870)	(948,864)	(946,391)

Note: See Appendix 3.

APPENDIX 6. GINO PROGRAM FOR THE BASE CASE

Model:
! market clearing conditions

```
 1) 21.58038352 - 1.11885844 * DHB101- 0.16215340 * DLB101=
  - 54.21800884 + 2.87044220 * SHB101+ 0.38789760 * SLB101   + 1.14817688 * SFG101;

 2) 28.81068480 - 0.40538349 * DHB101- 1.50802659 * DLB101=
  - 52.69345181 + 1.24127230 * SHB101+ 2.87044220 * SLB101 + 0.49650892 * SFG101;

 3) 48.38885798 - 0.54959651 * DHB101- 0.17215861 * DLB101 - 2.12765957 * DFG101 =
  - 24.60079814 + 1.66666667 * SFG101;

 4) 24.74978745 - 1.11885844 * DHB102- 0.16215340 * DLB102=
  - 54.43054436 + 2.87044220 * SHB102+ 0.38789760 * SLB102 + 1.14817688 * SFG102;

 5) 33.54063852 - 0.40538349 * DHB102- 1.50802659 * DLB102=
  - 53.94440376 + 1.24127230 * SHB102+ 2.87044220 * SLB102 + 0.49650892 * SFG102;

 6) 49.64530644 - 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102 =
  - 25.47686035 + 1.66666667 * SFG102;

 7) 25.31609856 - 1.11885844 * DHB2  - 0.16215340 * DLB2  =
  - 53.08112095 + 4.41988950 * SHB2  + 0.55248619 * SLB2  + 0.12026910 * SFG2;

 8) 33.99768677 - 0.40538349 * DHB2  - 1.50802659 * DLB2  =
  - 73.02373198 + 2.02578269 * SHB2  + 4.41988950 * SLB2  + 0.05512334 * SFG2;

 9) 48.60618240 - 0.54959651 * DHB2  - 0.17215861 * DLB2  - 2.12765957 * DFG2  =
  - 5.86088096 + 0.68027211 * SFG2;

10) 23.99047453 - 1.11885844 * DHB3  - 0.16215340 * DLB3  =
  - 98.36772546 + 5.63798220 * SHB3  + 0.89020772 * SLB3  + 1.27053120 * SFG3;

11) 32.40788842 - 0.40538349 * DHB3  - 1.50802659 * DLB3  =
  -105.80186864 + 2.37388724 * SHB3  + 5.63798220 * SLB3  + 0.53496050 * SFG3;

12) 48.95824397 - 0.54959651 * DHB3  - 0.17215861 * DLB3  - 2.12765957 * DFG3   =
  - 19.95634393 + 1.40845070 * SFG3;

13) 22.41387463 - 1.11885844 * DHB4  - 0.16215340 * DLB4  =
  - 23.41910423 + 1.84243964 * SHB4  + 0.25412961 * SLB4;

14) 30.05908982 - 0.40538349 * DHB4  - 1.50802659 * DLB4  =
  - 31.70529695 + 0.85768742 * SHB4  + 1.84243964 * SLB4;

15) 48.15536160 - 0.54959651 * DHB4  - 0.17215861 * DLB4   - 2.12765957 * DFG4   =
  - 15.66903970 + 1.14942529 * SFG4;

16) 24.10434195 - 1.11885844 * DHB5  - 0.16215340 * DLB5  =
```

- 40.59191971 + 2.63157895 * SHB5 + 0.32894737 * SLB5 + 1.07411386 * SFG5;

17) 32.33947367 - 0.40538349 * DHB5 - 1.50802659 * DLB5 =
- 40.48881390 + 1.05263158 * SHB5 + 2.63157895 * SLB5 + 0.42964554 * SFG5;

18) 47.80756429 - 0.54959651 * DHB5 - 0.17215861 * DLB5 - 2.12765957 * DFG5 =
- 27.89175929 + 2.04081633 * SFG5;

19) 24.29376878 - 1.11885844 * DHB6 - 0.16215340 * DLB6 =
- 31.02306175 + 2.63157895 * SHB6 + 0.32894737 * SLB6 + 0.42105263 * SFG6;

20) 32.62038520 - 0.40538349 * DHB6 - 1.50802659 * DLB6 =
- 38.21746689 + 1.05263158 * SHB6 + 2.63157895 * SLB6 + 0.16842105 * SFG6;

21) 48.29308925 - 0.54959651 * DHB6 - 0.17215861 * DLB6 - 2.12765957 * DFG6 =
- 7.15371281 + 0.80000000 * SFG6;

22) 22.97116079 - 1.11885844 * DHB7 - 0.16215340 * DLB7 =
- 24.86919375 + 2.63157895 * SHB7 + 0.32894737 * SLB7 + 0.16842105 * SFG7;

23) 30.64053721 - 0.40538349 * DHB7 - 1.50802659 * DLB7 =
- 32.32140751 + 1.05263158 * SHB7 + 2.63157895 * SLB7 + 0.06736842 * SFG7;

24) 46.30235453 - 0.54959651 * DHB7 - 0.17215861 * DLB7 - 2.12765957 * DFG7 =
- 6.69613036 + 0.80000000 * SFG7;

25) 23.90935289 - 1.11885844 * DHB8 - 0.16215340 * DLB8 =
- 47.89123415 + 3.61596010 * SHB8 + 0.37406484 * SLB8;

26) 32.05344796 - 0.40538349 * DHB8 - 1.50802659 * DLB8 =
- 64.36619865 + 1.62094763 * SHB8 + 3.61596010 * SLB8;

27) 48.62114614 - 0.54959651 * DHB8 - 0.17215861 * DLB8 - 2.12765957 * DFG8 =
- 43.83424018 + 3.03030303 * SFG8;

28) 23.43085387 - 1.11885844 * DHB9 - 0.16215340 * DLB9 =
- 21.69000463 + 1.90217391 * SHB9 + 0.27173913 * SLB9;

29) 31.47219787 - 0.40538349 * DHB9 - 1.50802659 * DLB9 =
- 28.69410624 + 0.81521739 * SHB9 + 1.90217391 * SLB9;

30) 47.45767105 - 0.54959651 * DHB9 - 0.17215861 * DLB9 - 2.12765957 * DFG9 =
- 15.17358103 + 1.21951220 * SFG9;

31) 24.75614653 - 1.11885844 * DHB10 - 0.16215340 * DLB10 =
- 42.77741116 + 3.61596010 * SHB10 + 0.37406484 * SLB10;

32) 33.42776068 - 0.40538349 * DHB10 - 1.50802659 * DLB10 =
-58.86067513 + 1.62094763 * SHB10 + 3.61596010 * SLB10;

33) 48.19607888 - 0.54959651 * DHB10 - 0.17215861 * DLB10 - 2.12765957 * DFG10 =

- 39.86663777 + 3.03030303 * SFG10;

34) 33.54988125 - 2.22222222 * DHB11 - 0.44444444 * DLB11 =
- 38.60433957 + 2.63157895 * SHB11 + 0.32894737 * SLB11 + 0.63411541 * SFG11;

35) 46.68492741 - 1.11111111 * DHB11 - 2.22222222 * DLB11 =
- 46.90825808 + 1.05263158 * SHB11 + 2.63157895 * SLB11 + 0.25364616 * SFG11;

36) 66.97856382 - 1.45061728 * DHB11 - 0.45679012 * DLB11 - 2.77777778 * DFG11 =
- 14.14473024 + 1.20481928 * SFG11;

37) 28.94915635 - 1.42460042 * DHB121- 0.41695622 * DLB121=
- 52.95024162 + 2.87044220 * SHB121+ 0.38789760 * SLB121+ 1.14817688 * SFG121;

38) 43.27384362 - 0.45170257 * DHB121- 2.57123002 * DLB121=
- 51.97624857 + 1.24127230 * SHB121+ 2.87044220 * SLB121+ 0.49650892 * SFG121;

39) 51.68194839 - 0.69566632 * DHB121- 0.35929206 * DLB121- 2.12765957 * DFG121 =
- 22.98747602 + 1.66666667 * SFG121;

40) 30.88768543 - 1.42460042 * DHB122- 0.41695622 * DLB122=
- 54.39011263 + 4.41988950 * SHB122+ 0.55248619 * SLB122+ 0.12026910 * SFG122;

41) 45.79175711 - 0.45170257 * DHB122- 2.57123002 * DLB122=
- 70.68149091 + 2.02578269 * SHB122+ 4.41988950 * SLB122+ 0.05512334 * SFG122;

42) 50.51558088 - 0.69566632 * DHB122- 0.35929206 * DLB122- 2.12765957 * DFG122 =
- 6.57434424 + 0.68027211 * SFG122;

43) 17.79110898 - 0.55692056 * DHB13 - 0.11466011 * DLB13 =
- 23.17509607 + 2.06611570 * SHB13 + 0.20661157 * SLB13 + 0.22539444 * SFG13;

44) 21.02277131 - 0.03822004 * DHB13 - 0.98826099 * DLB13 =
- 19.21515554 + 0.66115702 * SHB13 + 2.06611570 * SLB13 + 0.07212622 * SFG13;

45) 39.93140945 - 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
-18.45899975 + 1.81818182 * SFG13;

46) 15.49383723 - 0.55692056 * DHB14 - 0.11466011 * DLB14 =
-15.38187119 + 2.06611570 * SHB14 + 0.20661157 * SLB14 + 0.22539444 * SFG14;

47) 20.69351671 - 0.03822004 * DHB14 - 0.98826099 * DLB14 =
-21.96097760 + 0.66115702 * SHB14 + 2.06611570 * SLB14 + 0.07212622 * SFG14;

48) 37.06491393 - 0.22485295 * DHB14 -0.09976919 * DLB14 - 1.81818182 * DFG14 =
-19.41053674 + 1.81818182 * SFG14;

! quantity linkage

49) EXP(DHB101)+ EXP(DHB102)+ EXP(DHB2) + EXP(DHB3) + EXP(DHB4)
+ EXP(DHB5) + EXP(DHB6) + EXP(DHB7) + EXP(DHB8) + EXP(DHB9)

+ EXP(DHB10) + EXP(DHB11) + EXP(DHB121) + EXP(DHB122)
+ EXP(DHB13) + EXP(DHB14) + 786047 = EXP(SHB101) + EXP(SHB102)
+ EXP(SHB2) + EXP(SHB3) + EXP(SHB4) + EXP(SHB5) + EXP(SHB6)
+ EXP(SHB7) + EXP(SHB8) + EXP(SHB9) + EXP(SHB10)
+ EXP(SHB11) + EXP(SHB121)+ EXP(SHB122) + EXP(SHB13) + EXP(SHB14);

50) EXP(DLB101)+ EXP(DLB102)+ EXP(DLB2) + EXP(DLB3) + EXP(DLB4)
+ EXP(DLB5) + EXP(DLB6) + EXP(DLB7) + EXP(DLB8) + EXP(DLB9)
+ EXP(DLB10) + EXP(DLB11) + EXP(DLB121) + EXP(DLB122)
+ EXP(DLB13) + EXP(DLB14) - 1066927 = EXP(SLB101) + EXP(SLB102)
+ EXP(SLB2) + EXP(SLB3) + EXP(SLB4) + EXP(SLB5) + EXP(SLB6)
+ EXP(SLB7) + EXP(SLB8) + EXP(SLB9) + EXP(SLB10)
+ EXP(SLB11) + EXP(SLB121)+ EXP(SLB122) + EXP(SLB13) + EXP(SLB14);

51) EXP(DFG101)+ EXP(DFG102)+ EXP(DFG2) + EXP(DFG3) + EXP(DFG4)
+ EXP(DFG5) + EXP(DFG6) + EXP(DFG7) + EXP(DFG8) + EXP(DFG9)
+ EXP(DFG10) + EXP(DFG11) + EXP(DFG121) + EXP(DFG122)
+ EXP(DFG13) + EXP(DFG14) + 84401464 = EXP(SFG101) + EXP(SFG102)
+ EXP(SFG2) + EXP(SFG3) + EXP(SFG4) + EXP(SFG5) + EXP(SFG6)
+ EXP(SFG7) + EXP(SFG8) + EXP(SFG9) + EXP(SFG10)
+ EXP(SFG11) + EXP(SFG121)+ EXP(SFG122) + EXP(SFG13)+ EXP(SFG14);

! price linkage (HB)

52) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(21.58038352- 1.11885844 * DHB101- 0.16215340 * DLB101) + 328.26 + 2757.31 + 2016.60);

53) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(22.41387463- 1.11885844 * DHB4 - 0.16215340 * DLB4) + 310.78 + 2795.62 + 2016.60);

54) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(23.90935289- 1.11885844 * DHB8 - 0.16215340 * DLB8) + 292.66 + 2756.95 + 2016.60);

55) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(23.43085387- 1.11885844 * DHB9 - 0.16215340 * DLB9) + 279.95 + 2780.30 + 2016.60);

56) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(33.54988125- 2.22222222 * DHB11 - 0.44444444 * DLB11) + 142.80 + 2963.60 + 2016.60);

57) 17.79110898- 0.55692056 * DHB13 - 0.11466011 * DLB13 =
LOG(EXP(28.94915635- 1.42460042 * DHB121- 0.41695622 * DLB121) + 253.60 + 2978.80 + 2016.60);

58) 15.49383723- 0.55692056 * DHB14 - 0.11466011 * DLB14 =
LOG(EXP(21.58038352- 1.11885844 * DHB101- 0.16215340 * DLB101) + 328.26 + 2708.31 + 1995.60);

59) 23.99047453- 1.11885844 * DHB3 - 0.16215340 * DLB3 =
LOG(EXP(22.41387463- 1.11885844 * DHB4- 0.16215340 * DLB4) + 37.13);

60) 24.74978745- 1.11885844 * DHB102- 0.16215340 * DLB102 =
LOG(EXP(22.41387463- 1.11885844 * DHB4 - 0.16215340 * DLB4) + 45.68);

61) 22.97116079- 1.11885844 * DHB7 - 0.16215340 * DLB7 =
LOG(EXP(23.90935289- 1.11885844 * DHB8 - 0.16215340 * DLB8) + 70.11);

62) 25.31609856- 1.11885844 * DHB2 - 0.16215340 * DLB2 =
LOG(EXP(24.74978745- 1.11885844 * DHB102- 0.16215340 * DLB102) + 66.22);

63) 24.10434195- 1.11885844 * DHB5 - 0.16215340 * DLB5 =
LOG(EXP(24.74978745- 1.11885844 * DHB102- 0.16215340 * DLB102) + 42.78);

64) 24.29376878- 1.11885844 * DHB6 - 0.16215340 * DLB6 =
LOG(EXP(24.74978745- 1.11885844 * DHB102- 0.16215340 * DLB102) + 55.09);

65) 24.75614653- 1.11885844 * DHB10 - 0.16215340 * DLB10 =
LOG(EXP(23.43085387- 1.11885844 * DHB9 - 0.16215340 * DLB9) + 79.95);

66) 30.88768543- 1.42460042 * DHB122- 0.41695622 * DLB122=
LOG(EXP(28.94915635- 1.42460042 * DHB121- 0.41695622 * DLB121) + 142.78);

! price linkage (LB)

67) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(28.81068480- 0.40538349 * DHB101- 1.50802659 * DLB101) + 328.26 + 2117.61 + 1614.30);

68) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(30.05908982- 0.40538349 * DHB4 - 1.50802659 * DLB4) + 310.78 + 2155.92 + 1614.30);

69) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(32.05344796- 0.40538349 * DHB8 - 1.50802659 * DLB8) + 292.66 + 2117.25 + 1614.30);

70) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(31.47219787- 0.40538349 * DHB9 - 1.50802659 * DLB9) + 279.95 + 2140.60 + 1614.30);

71) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(46.68492741- 1.11111111 * DHB11 - 2.22222222 * DLB11) + 142.80 + 2761.90 + 1614.30);

72) 21.02277131- 0.03822004 * DHB13 - 0.98826099 * DLB13 =
LOG(EXP(43.27384362- 0.45170257 * DHB121- 2.57123002 * DLB121) + 253.60 + 2315.10 + 1614.30);

73) 20.69351671- 0.03822004 * DHB14 - 0.98826099 * DLB14 =
LOG(EXP(28.81068480- 0.40538349 * DHB101- 1.50802659 * DLB101) + 328.26 + 2131.61 + 1620.30);

74) 32.40788842- 0.40538349 * DHB3 - 1.50802659 * DLB3 =
LOG(EXP(30.05908982- 0.40538349 * DHB4 - 1.50802659 * DLB4) + 37.13);

75) 33.54063852- 0.40538349 * DHB102- 1.50802659 * DLB102=
LOG(EXP(30.05908982- 0.40538349 * DHB4 - 1.50802659 * DLB4) + 45.68);

76) 30.64053721- 0.40538349 * DHB7 - 1.50802659 * DLB7 =
LOG(EXP(32.05344796- 0.40538349 * DHB8 - 1.50802659 * DLB8) + 70.11);

77) 33.99768677- 0.40538349 * DHB2 - 1.50802659 * DLB2=

LOG(EXP(33.54063852- 0.40538349 * DHB102- 1.50802659 * DLB102) + 66.22);

78) 32.33947367- 0.40538349 * DHB5 - 1.50802659 * DLB5 =
LOG(EXP(33.54063852- 0.40538349 * DHB102- 1.50802659 * DLB102) + 42.78);

79) 32.62038520- 0.40538349 * DHB6 - 1.50802659 * DLB6 =
LOG(EXP(33.54063852- 0.40538349 * DHB102- 1.50802659 * DLB102) + 55.09);

80) 33.42776068- 0.40538349 * DHB10 - 1.50802659 * DLB10 =
LOG(EXP(46.68492741- 1.11111111 * DHB11 - 2.22222222 * DLB11) + 336 + 212.78);

81) 45.79175711- 0.45170257 * DHB122- 2.57123002 * DLB122=
LOG(EXP(43.27384362- 0.45170257 * DHB121- 2.57123002 * DLB121) + 142.78);

! price linkage (FG)

82) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(48.38885798- 0.54959651 * DHB101- 0.17215861 * DLB101 - 2.12765957 * DFG101) + 48.08);

83) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(49.64530644- 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102) + 38.60);

84) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(48.95824397- 0.54959651 * DHB3 - 0.17215861 * DLB3 - 2.12765957 * DFG3) + 47.55);

85) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(48.15536160- 0.54959651 * DHB4 - 0.17215861 * DLB4 - 2.12765957 * DFG4) + 48.30);

86) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(47.45767105- 0.54959651 * DHB9 - 0.17215861 * DLB9 - 2.12765957 * DFG9) + 35.95);

87) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(66.97856382- 1.45061728 * DHB11 - 0.45679012 * DLB11 - 2.77777778 * DFG11) + 9.07);

88) 39.93140945- 0.22485295 * DHB13 - 0.09976919 * DLB13 - 1.81818182 * DFG13 =
LOG(EXP(51.68194839- 0.69566632 * DHB121- 0.35929206 * DLB121 - 2.12765957 * DFG121) + 38.60);

89) 37.06491393- 0.22485295 * DHB14 - 0.09976919 * DLB14 - 1.81818182 * DFG14 =
LOG(EXP(48.38885798- 0.54959651 * DHB101- 0.17215861 * DLB101 - 2.12765957 * DFG101) + 48.08);

90) 48.60618240- 0.54959651 * DHB2 - 0.17215861 * DLB2 - 2.12765957 * DFG2 =
LOG(EXP(49.64530644- 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102) + 21.77);

91) 48.60618240- 0.54959651 * DHB2 - 0.17215861 * DLB2 - 2.12765957 * DFG2 =
LOG(EXP(50.51558088- 0.69566632 * DHB122- 0.35929206 * DLB122 - 2.12765957 * DFG122) + 14.24);

92) 47.80756429- 0.54959651 * DHB5 - 0.17215861 * DLB5 - 2.12765957 * DFG5 =
LOG(EXP(49.64530644- 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102) + 15.09);

93) 48.29308925- 0.54959651 * DHB6 - 0.17215861 * DLB6 - 2.12765957 * DFG6 =
LOG(EXP(49.64530644- 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102) + 17.92);

94) 46.30235453- 0.54959651 * DHB7 - 0.17215861 * DLB7 - 2.12765957 * DFG7 =
LOG(EXP(49.64530644- 0.54959651 * DHB102- 0.17215861 * DLB102 - 2.12765957 * DFG102) + 17.61);

95) 48.62114614- 0.54959651 * DHB8 - 0.17215861 * DLB8 - 2.12765957 * DFG8 =
LOG(EXP(48.15536160- 0.54959651 * DHB4 - 0.17215861 * DLB4 - 2.12765957 * DFG4) + 14.15);

96) 48.19607888- 0.54959651 * DHB10 - 0.17215861 * DLB10 - 2.12765957 * DFG10 =
LOG(EXP(47.45767105- 0.54959651 * DHB9 - 0.17215861 * DLB9 - 2.12765957 * DFG9) + 28.66);

END